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Author	Platt, Geoffrey K.
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Children and developmental co-ordination: entropy, resistance training and athletic fitness.

Geoffrey K. Platt

PhD

Institute of Sport, Physical Education
and Health Sciences
Moray House School of Education
The University of Edinburgh

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Declaration

I declare that this is entirely my own work and that it has not been submitted in any form for another degree or professional qualification

Geoffrey K. Platt

Date……………30th June 2010……………………

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Abstract

Developmental Co-ordination Disorder (D.C.D.) or Dyspraxia, is a condition in which children experience movement difficulties that vary from child-to-child and from day-to-day, according to health and level of exhaustion (Macintyre, 2001). Without a specific definition or essential symptom, identifying a satisfactory test for D.C.D. has proved difficult. Since 1992, the Movement A.B.C. Test (Henderson & Sugden, 1992) has been used in the U.K. and the Bruinink's-Oseretsky Test (Bruininks, 1978) in the U.S.A. A comparison of the results found significant differences and a correlation of only 0.80, that neither test was better, but that the best results were achieved by undertaking both tests. (Crawford et al., 2001). These differences affect all research into D.C.D and every diagnosis of the condition.

Research has shown muscular weakness, particularly in the fingers, hands and wrists, to be a symptom of D.C.D. Raynor (1989; 2001) confirmed this with strength tests of the muscles on the upper leg, using a cybex machine. My second study employed two isokinetic and two isometric tests and used a grip dynamometer to evaluate the strength of the muscles of the fingers, hands and wrists. The most successful intervention involves physiotherapists assessing individual children's movement difficulties, identifying the causes and designing individual strength programmes to reduce the symptoms by 72%. (Lee and Smith, 1998) My third study attempted to replicate these results without the personal assessments or physiotherapists which made it financially unviable. *Study 1:* This research employed an approximate entropy device (Arehimedes, 2006; Christakis, 2006), attached to a belt secured with Velcro around the subject's waist, close to the centre of gravity. Following familiarisation, the participants [forty six children, 19 female; 27 male; (mean ±SD age = 9.5 ± 0.5 years]; walked forty metres along a straight, flat, level path (school gymnasium, wooden floor) at a self-determined pace. Unfortunately, the results were inconsistent, although the system displayed an interesting level of sensitivity that indicated that further research is justified as the technology improves, with some evidence (ns) of the potential for research focusing on the

vertical component of the entropy value. *Study 2:* A battery of four strength tests were selected that required no specialist equipment and which were suitable for supervision by P.E. teachers. These were the Sargent jump, the triple jump, the grip dynamometer and the leg and back dynamometer The participants [472 primary school children, 243 males and 229 females; mean ±SD age 9.2 ± 0.9 years] were assessed for strength. They were then assessed using the Movement A.B.C. Test and the results were compared in order to identify whether a lack of strength was a factor in the incidence of D.C.D. Results showed a significant correlation ($p < 0.01$) between the Movement A.B.C. Test scores and all of the strength tests. *Study 3:* This study employed the same participants as study two but divided them into intervention and control groups. Restrictions on space, staff and equipment required the use of the participants from one school, selected at random, as the control group and the participants from the other four schools as the intervention group. The intervention group [341 primary school children, 169 males and 172 females; mean ±SD age 9.32 ± 0.8 years] then undertook a six week strength programme (two 30 minute sessions per week) in their normal school environment, and in addition to their curricular P.E. lessons. This programme involved sprinting, hopping, and jumping based on the "Elevating Athletics" programme (see appendix 9)(U.K.A., 2006). The strength tests and Movement A.B.C. Test were administered pre and post the six week programme to assess whether a general strength programme is a positive intervention in D.C.D, and compared with the control group [131 primary school children, 74 males and 57 females; mean ±SD age 9.23 ± 0.9 years]. Post the six week strength programme the intervention group scores improved significantly in the Movement A.B.C. test and in each of its three component parts, dexterity, ball skills and balance, whilst the results of the control group showed no significant change.

This research has highlighted the need for an improved assessment tool by which to identify children with D.C.D. Further, it has shown that improvement is possible for children within the age range 8 to 11 years following a six week strength intervention.

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Chapter 1: Introduction

It is ironic that on the bi-centenary of the birth of Charles Darwin, the English naturalist and graduate of the University of Edinburgh, author of the 1859 book, *The Origin of Species* and of the theory of natural selection (Darwin, 1859), our offspring are evolving into obese children (W.H.O., 1992) with severe difficulties in controlling their movements (*British Medical Journal*, 1962). Inability to adapt to a sedentary lifestyle with easy access to large quantities of rich and unsuitable food is currently reducing their chances of survival, rather than improving them.

This dissertation will recognise the substantial amount of research currently being undertaken into the issue of obesity and focus instead on the movement difficulties, which it will refer to as Developmental Coordination Disorder (D.C.D.). Professionals from a wide variety of fields, centred around medicine and education, have identified these movement difficulties and the problems that they have been shown to cause as the children develop and grow older.

1.1: History of Movement Difficulties in Children

Since the start of the Industrial Revolution in the late eighteenth century there have been doubts raised about the health and fitness of the younger generations (Baden-Powell, 1908; Nordau, 1892). The movement away from an agricultural economy to an urban industrial economy reduced the reliance on manual labour by increasing the use of alternative forms of energy such as coal, steam and water, causing fundamental changes to a range of socio-economic and cultural factors and eventually to the lifestyles of all working people (O'Brien & Quinault, 1993).

The end of the nineteenth century was a time of international turmoil when Great Britain was facing the prospect of war in several theatres around the world (Ensor, 1963) and the belief that young people were becoming less fit and strong led to a fear that this would be reflected in the ability to find and train sufficient soldiers and doubt in the strength of the army and in its ability to win wars. In 1892, Max Nordau, a German who studied in Italy and who wrote about French philosophy, published a book in Germany entitled, "Degeneration". It was translated into English and published in England in 1895 and was so popular that it required six reprints in the next six months and is still published today. Nordau starts his book by expressing his view that:

> (The human body's) own new discoveries and progress have taken civilised humanity by surprise. It has had no time to adapt itself to its changed conditions of life. We know that our organs acquire by exercise an ever greater functional capacity, that they develop by their own activity; and can respond to nearly every demand made upon them. If they are obliged to fulfil, without transition, a multiple of their usual task, they soon give out entirely
>
> (Nordau, 1892, p.40).

Nordau then went on to introduce his concept of "Fin de siècle" which he described as "The Dusk of the nations" and the "Autumn of human life" whereby degeneration would lead to the eventual decline and fall of the human race, explaining that the Industrial Revolution had led to large towns – more railways – more alcohol consumption – more food – less exercise, and – degeneration. The British Establishment, always rather more conservative than their continental colleagues, took a little longer to react to the same situation. In 1899 Lieutenant-Colonel Robert Baden-Powell published a book entitled "Aids to Scouting" aimed at soldiers (Baden-Powell, 1899). The next year he returned home, promoted to Major General and a popular hero after his success in defending the city during the Siege of Mafeking in the course of the Boer War. When he heard that the Director General of the War Office had issued a memorandum pointing out that between 40 and 60% of those applying to enlist in the Army were unfit for service, he was prompted to revise his book so that it addressed teenage boys and highlighted the need for outdoor physical activities and re-publish it as "Scouting for Boys" as Europe prepared for the First World War (Baden-Powell, 1908).

The first medical reference to children experiencing movement difficulties was produced when Samuel T. Orton, a Consultant Neurologist from New York, U.S.A. wrote a book entitled "Reading, Writing and Special Problems in Children" in 1937 and spoke of a "developmental apraxia" and suggested that the cause may be what he described as a "double left handedness".

> These children seem to be equipped with a lack of skill on both sides comparable to that of the left hand in a strongly right-handed person. The inability in this condition is for the carrying out of any complex trained movements whether they be of hand, foot, or body.
>
> (Orton, 1937, p.1)

Ironically, whilst the First World War focussed attention on these problems with movement skills, the Second World War appears to have distracted attention from the problems and little further research was published on the subject until the early 1960s. After the Second World War the restrictions that had been imposed on urban children in order to ensure their safety during the Blitz and which had prevented them from playing in the streets, were lifted and they swiftly returned to spending their days running, jumping, playing football and climbing trees. In the 1950s greater affluence, mass car ownership and modern housing estates combined with an increased perception of danger from paedophiles following the widely-publicised Moors Murders of Hindley and Brady (Williams, 1968) persuaded parents that children could best be protected within the home, entertained by their new electronic toys of television and radio and later by videos, video games and computers.

In the early 1960s attention once again focussed on movement disorders. In the U.S.A. Dr A. Jean Ayres, a prolific academic from the University of Southern California specialising in psychology and occupational therapy started a forty-year-long career investigating D.C.D. In the U.K. a paper entitled "Clumsy Children" was published on Saturday 22nd December 1962 (*British Medical Journal,* 1962). The paper highlighted research that had been undertaken in Sweden, Holland and the United Kingdom, suggesting that many classroom discipline problems were the result of clumsy children struggling with their movement difficulties rather than any lack of personal discipline. It is at this time that there was a general acceptance that a problem exists and that further research was required in order to establish the causes of the disorder and to identify a viable solution for it. A number of different specialists have participated in the research effort, including:

- Teachers
- Physical Education Specialists
- Special Educational Needs Co-ordinators (SENCO)
- Educational Psychologists
- Social workers
- Doctors/ Paediatricians
- Orthopaedic surgeons
- Speech and language therapists
- Occupational therapists
- Physiotherapists

Around 1965, in an effort to define a range of educational difficulties that had been identified but which could not be explained, scientists established the term "specific learning difficulties". The term refers to problems identified in an educational setting usually in reading, writing, spelling and number work, sometimes called the 'developmental tasks' of the school-age child. They include:

- Dyslexia (difficulties with spelling and reading);
- Asperger's Syndrome (difficulties making friends, seeing things literally);
- D.C.D. (difficulties with ball skills, poor handwriting at speed);
- Attention Deficit Hyperactivity Disorder (difficulty concentrating);
- Deficit of Attention and Motor Perception (difficulty in paying attention and movement control);
- Dysgraphia (difficulty in writing);
- Dyscalculia (difficulty with sums);

(Kirby & Drew, 2003, p.2)

People with specific learning disorders are likely to be of above average intelligence and are unlikely to suffer from only one of these conditions. "Co-morbidity is the rule rather than the exception" (Kaplan, Wilson, Dewey & Crawford, 1998). These difficulties are unexpected when the general intellectual ability of the pupil is taken into account (Frith, 1980). There is a debate currently taking place within the scientific community as to whether these people are all suffering with the same condition of "specific learning difficulties" that is manifested in a range of symptoms that vary from person to person, or whether each condition listed above has a separate cause and a separate list of symptoms (Geuze, 2007). This debate highlights the low level of current knowledge on these conditions and the need for further research.

Movement skills disorders, referred to here as D.C.D., are also referred to by a number of other names, usually depending on the academic specialism of the person using the name:

- dyspraxia
- clumsy child syndrome
- developmental agnosia and apraxia
- learning difficulties/disabilities/disorders
- minimal cerebral palsy
- minimal cerebral dysfunction
- minimal brain dysfunction
- minimal motor dysfunction
- motor learning difficulties
- neurodevelopmental dysfunction
- perceptual/perceptuo-motor dysfunction

- physical awkwardness
- specific learning difficulties
- sensori-motor dysfunction
- spatial problems
- visuo-motor difficulty

(Boon, 2002, p.10)

Labelling a condition has the advantage that it acknowledges that a problem exists and assists in making applications for funding for research into a named condition rather than a more abstract problem. Unfortunately, it may also be seen as an excuse for poor behaviour by some families and as a justification for failing to attempt to raise standards. A label can mean:

- Acknowledgement for the parent of worries and concerns, and confirmation of the condition: allows others to see the parent as not just 'another over-anxious parent'.
- The provision of funds or services for the child.
- The provision of a cohort of individuals with signs and symptoms that may be useful for research.
- Allowing individuals working with the child to read up around the condition and consider what type of support is required.
- It may be used in legal cases as a reference point to consider one child's support compared to others.
- It may be used to plan service delivery or for baseline assessment and in-school remediation programmes.
- It may suggest negative connotations and may mean that individuals who come into contact with the child have preconceived ideas about the

strengths and difficulties based on their experience of others with the same label they have come into contact with, who could even have been atypical.

- Placing children in very small boxes and not seeing them from all perspectives - this may lead to missing a diagnosis.
- The child perhaps ends up with many labels but not the right type of help.
- The child then being 'tattooed' for life with what they can't do rather than what they can do.
- One label does not carry as much weight as another; for instance, medical labels may seem more important than educational ones (e.g. epilepsy versus dyslexia).

(Kirby & Drew, 2003, pp.1-2)

1.2: Causes of D.C.D.

A considerable amount of research has been undertaken by scientists from a wide variety of specialisms in an attempt to establish the cause of D.C.D., however almost no progress had been made until very recently. Since Orton's original suggestion that the condition may be caused by lesions in the brain, (Orton, 1937), most scientists have discounted this view, choosing instead to believe that the condition is caused by a lack of neural links (Portwood, 1998), but lacking the scientific evidence to support their views. Only very recently have technological advances permitted the development of scanners capable of scanning human brains in sufficient detail so as to show the lesions associated with the incidence of movement difficulties in children (Geuze, 2007). Further research is currently being undertaken to pursue this recent advance and establish the precise causes of the condition.

Symptoms similar to those of D.C.D. have been identified in children whose mothers have consumed alcohol during pregnancy even in relatively insignificant amounts. This has been called Foetal Alcohol Syndrome, and there are a number of symptoms, (McCreight, 1997) but they are relatively minor and may appear insignificant when any movement difficulties are identified during an assessment of the child away from the presence of the mother many years after the children are born. Almost all social and recreational drugs are capable of crossing the placenta and causing death and congenital deformation of the baby (Pollard, 2007). Little evidence exists that these drugs can cause movement disorders, as research has focussed on the higher-end problems of causing death and congenital deformation rather than the lesser issues of causing movement difficulties. The strength and nature of these substances must however arouse a fear that they may be the cause of some movement difficulties in children.

The lack of a precise cause for D.C.D. has led to the American Psychiatric Association (A.P.A.) publishing diagnostic criteria for the condition in their Diagnostic and Statistical Manual of Mental Disorders (D.S.M.) that has caused them to unusually specify that "the coordination difficulties are not due to a general medical condition" (American Psychiatric Association, 2000). The manual is widely used in the United States and in varying degrees around the world, by clinicians, researchers, psychiatric drug regulation agencies, health insurance companies, pharmaceutical companies and policy makers. The full definition of D.C.D. in the manual is:

> ......a marked impairment in the development of motor coordination (Criterion A). The diagnosis is made only if this impairment significantly interferes with

academic achievement or activities of daily living (Criterion B). The diagnosis is made if the coordination difficulties are not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and the criteria are not met for Pervasive Developmental Disorder (Criterion C). If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it (Criterion D). (American Psychiatric Association, 2000, p.58)

1.3: Symptoms of D.C.D.

There are a range of symptoms for D.C.D. but none of them are essential for a diagnosis. The symptoms and skills of those with the disorder may vary from hour-to-hour and from day-to-day, depending on their tiredness and ability to concentrate, making diagnosis difficult. The children's abilities do improve with age and they achieve the usual targets of walking, running, writing and talking just within the 'normal' time span, although their performance never quite reaches the same level as that of the average child.

The areas affected are:

- Gross motor skills
- Fine motor skills
- Speech and language
- Social skills
- Attention and concentration
- Learning

- Visual motor skills

The primary problems include:

- Low muscle tone
- Weak hands and fingers
- Fast fatigue of the muscles
- Poor joint stability
- Inability to conceptualise movement, particularly across their midline
- Inability to execute movements, particularly across their midline
- Poor coordination
- Poor balance
- Poor attention
- Inability to screen out the non relevant
- Poor proprioceptive feedback
- Poor tactile feedback
- Overall lack of inhibition in the central nervous system
- Hyperactivity
- Poor eye movements

Secondary problems of D.C.D. are:

- Lack of confidence
- Poor self esteem
- Refusal to participate
- Avoidance
- Frustration
- Unhappiness

- Loneliness
- Becoming withdrawn
- Acting the clown

(Kirby & Drew 2004, p12)

1.4: Incidence of D.C.D.

Most researchers estimate the incidence of D.C.D. at between 5 and 10% of the population (Gubbay, 1975; Henderson & Hall, 1982; Portwood, 1996) with three times as many boys as girls affected (Gordon and McKinlay, 1980; Henderson and Hall, 1982; Hoare and Larkin, 1991; Keogh, Sugden, Reynard & Calkins, 1979). Some assessment tools require their results to be standardised. The Movement A.B.C. Test, for example is standardised to allow for 5% of those tested being positive for the disorder.

1.5: Assessment of D.C.D.

A number of tests have been designed in order to assess movement difficulties and to identify those with D.C.D. These include:

- The Abilities of Young Children test (Griffiths, 1970)
- Southern California Sensory Integration Test (Ayres, 1972)
- Bruininks Oseretsky Test of Motor Proficiency (Bruininks, 1978)
- Examination of the Child with Minor Neurological Dysfunction(Touwen, 1979)
- Kinaesthetics and Sensitivity Test (Laszlo & Bairstow, 1985)
- Test of Gross Motor Development (Ulrich, 1985)
- Movement Assessment Battery for Children

(Henderson & Sugden, 1992)

The tests are less than satisfactory and none has yet secured universal recognition. Each test relies on subjective assessment from trained assessors which leads to low levels of reliability and validity. A comparison of the two most popular tests, the Movement A.B.C. Test and the Bruininks Oseretsky Test found a co-incidence factor of 0.80. (Crawford, Wilson & Dewey, 2001). None of the tests provide any indication of the severity or cause of the individual child's disorder, meaning that a considerable amount of follow up work is required in every case.

1.6: Interventions for D.C.D.

There is no known cure for D.C.D. or for any of the symptoms of the condition (Ball, 2002; Macintyre, 2001). Assistance for those with the condition usually focuses on process or task orientated interventions following a detailed assessment of the child's abilities and the tasks with which they find the most difficulty and practising those abilities and tasks again and again until they are mastered. Ultimately, most people learn coping strategies as they grow older. Physiotherapy has been shown to produce a 72% improvement in movement skills on those with movement disorders (Lee & Smith, 1998), but the assessment and intervention both need to be undertaken on an individual basis and are extremely time consuming for a specialist physiotherapist, putting it beyond economic viability. Clearly, general interventions can work, but ideally ways need to be found that involve group work rather than individual work, that require less specialist training for the person undertaking the assessment and intervention and possibly to even remove the need for assessment due to the intervention having some universal benefit for all participants in addition to its specific application as an intervention in cases of movement disorder.

1.7: Statement of the problem

It is necessary to find a test that meets basic standards of reliability and validity and a viable intervention that makes a substantial improvement to the majority of movement skills in most cases with movement disorders. In the case of a disorder in which there is no known cause, no known test and in which the symptoms vary both between each person with the condition, and from hour-to-hour and from day-to-day with each child with movement skills, this is challenging.

1.8: Aims of the study

- To investigate whether strength is a factor in the incidence of D.C.D.;
- To consider whether strength training may be a useful intervention in cases of D.C.D.;
- To investigate further the strengths and weaknesses of the Movement A.B.C. Test and ascertain whether a test which is more sensitive, more refined and more objective for D.C.D. may be identified.

It is proposed to assess children aged between 8 and 11 years for D.C.D. and then to measure their strength so that its effect as a factor in the incidence of D.C.D. may be evaluated. After completing an intervention to improve their strength the children will repeat the assessment for D.C.D. and the battery of strength tests so that any changes in their strength and movement skills may be identified.

Chapter 2 Review of the Literature

2.1: Introduction

> But we do know what the Greeks knew: that intelligence and skill can only function at the peak of their capacity when the body is healthy and strong; that hardy spirits and tough minds usually inhabit sound bodies
>
> (Kennedy, 1960).

Child fitness levels are the focus of a great deal of government attention, with almost daily reports in the national press relating to the latest scientific research and updates in government policy. Childhood obesity is recognised by the World Health Organisation as one of the Top Ten Problems facing us as we enter the 21st century (W.H.O., 1992). Cardiovascular fitness levels among 10-year-old children are dropping at the rate of 4.8% per decade (Sandercock, Voss, McConnell& Rayner, 2010). Sports coaches and P.E. teachers complain about the lack of movement skills of our children. Government advisors argue about which of these aspects of fitness should be given priority in their attempts to improve the health of the nation (B.B.C., 2009). The health and wellbeing of our children is the cause of almost universal concern.

Several researchers have argued that an active lifestyle is even more important for those who have disabilities (Cooper, Quatrano, Axelson, Harlan, Stineman, Franklin, ...& Painter 1999; Steele, Kalnins, Jutai, Stevens, Bortolussi & Biggar, 1996; van der Ploeg, van der Beek, van der Woude & van Mechelen, 2004). Their argument is based on the beneficial effects of exercise on the functional abilities of persons with disabilities, combined with a corresponding reduction in the risk of secondary conditions that are physical, medical, cognitive, emotional, or psychosocial consequences and which a person with a primary disabling condition (e.g., spina bifida) is predisposed to experience (Simeonsson, McMillen & Huntingdon, 2002).

Obesity has benefited from considerable research (Berkey, Rockett, Field, Gillman, Frazier, Camargo & Colditz, 2000; Booth, Sallis, Ritenbaugh, Hill, Birch, Franz, ...& Hays, 2001; Smith & Biddle, 2008) and substantial efforts have been made to reduce the adiposity of school-age children by taking statutory powers to close fast food restaurants near schools (The Independent, 2009), by attempting to control school-time meals for their nutritional content (Oliver, 2009) and by improving labelling of the content of food supplied in restaurants and stores (F.S.A., 2009). The Department of Schools, Children and Families is attempting to increase statutory provision of Physical Education for all children in an attempt to improve their fitness (D.C.S.F., 2009). Little is being done to improve the children's movement skills, possibly due a lack of knowledge of the subject.

Movement disorders were first identified by educationalists who were working with children on a daily basis in an increasingly formal educational environment. The problems were then brought to the attention of members of the medical profession, who referred them to occupational therapists, physiotherapists and others thought to be able to help the children. Parents, generally dissatisfied with the treatment offered, wrote self-help books to assist parents who followed them. The books that currently exist on movement skills difficulties therefore fall into three types:

- Educational books;
- Medical books;
- Self help books.

For the last forty years research into movement disorders in children in the United Kingdom has been dominated by one group of teachers and educationalists, so that a search on the British Library database reveals no less that four hundred books and papers published by just five members of this group. As a result of this dominance, popular views on the subject have become entrenched despite a general lack of scientific support for some of the views expressed e.g. that there is no useful intervention for D.C.D. (Brookes, 2007b). The medical books are generally scientific journals of the highest standard and contain a wide range of observations about the condition and its effects, but, in the main focus on repeated practice of those skills that cause the children difficulties in order to improve performance. Self help books are generally written by those with the disorder, their parents, family and friends or their teachers and helpers. Their style and quality is variable and little, if any, of the material is evidenced or referenced, but they contain substantial quantities of anecdotal material. These books are, however, excellent for sharing substantial amounts of first-hand experience and stimulating original thought on the subject.

Within Sports Science there is a comparatively new area entitled 'Movement Skills' or 'Motor Learning' (Schmidt & Wrisberg, 2000) and within that 'Movement Skills Development', (Haywood & Getchell, 2005) but the scientists in this area do not yet appear to have focussed on the difficulties experienced in movement skills, particularly by children. This research will attempt to overcome any adverse influence from the perceived dominance of the entrenched views of the educationalists by starting from the rather more scientific and as yet, untapped research into Movement Science, and relating that to the movement skills difficulties literature and moving forward from there. It will also focus on attempting to identify a universal intervention, capable of generally increasing all movement skills across the majority of children with movement skills difficulties. A second focus will be to identify a quicker, cheaper, more convenient, more objective method of testing for D.C.D.

2.2: Review of Movement Science

Definitions of Movement

Movement

Actual observable change in position of any part of the body. The culminating act of underlying motor processes and perception.

Movement pattern

An organised series of related movements.

Movement skill

A pattern with accuracy, precision and control.

(Ripley, Daines & Barrett, 1997, p24)

Movement is the primary skill required by any person; as Gallahue puts it, "Learning to move is too important to be left to chance." (Gallahue & Ozmun 1995, p.528) We need to move in order to feed ourselves or to reproduce, to move away from predators or to find heat and cool, light and shade, friends and family and all those others things that we need or want. At birth we are small and unable to move in any way, even by rolling. We are totally dependant on our parents and require them to do everything for us. As soon as we are born we start to seek ways in which we can influence our environment. We learn that to cry brings an adult to attend to our needs. We learn that by gripping an adult's finger we can secure his or her complete attention. Movement starts to improve our situation. Research has shown that human movement starts before we are born, as early as in the sixth week of pregnancy (Kirby & Drew, 2003, p.20). There is anecdotal evidence from expectant mothers that those babies who experience movement difficulties in childhood may be identified by their lack of movement in the womb at this time, so these movement difficulties may start very early in our development, but this requires further research to be confirmed (Kirby & Drew, 2003, p.20).

Movement is a complex activity, requiring the co-ordination of physical and neural functions. From a purely physical aspect, it requires bones, lined with cartilage to reduce friction whilst moving, held together with ligaments, moved by muscles attached to the bones by tendons. Lack of muscle tone and weakness, particularly in the muscles of the hands and wrists has been shown to be a symptom of D.C.D. (Oliveira, Shim, Loss, Petersen, & Clark, 2006). No literature has been found that proposes or investigates any other physical difficulties which may cause movement difficulties in children and it is not pursued here.

The neural functions which control movement are complex. Moving well means:

- controlling the body as it moves
- coordinating different body parts so that movement is smooth
- gauging the correct amount of strength and speed
- understanding directionality
- being able to manipulate objects
- appreciating the rhythm of movements to aid repetition
- making safety decisions about when to move and where to move, and
- being able to stay still!

(Macintyre, 2002, p.2)

It was Bernstein, the father of modern Human Movement analysis, who described the human brain as a "black box" receiving collating, calculating and co-ordinating movements in a number of joints and who, shortly before his death in 1966 described the science of human movement and theories of motor co-ordination as "one of the most obscure branches of human and comparative physiology"(Magill, 2003, p.23). Perhaps it is fair to say that this science has only become understood since information technology became more advanced and more universally available. Movement changes throughout our lives. Our bodies increase in length, girth, weight, proportion, muscle tone and strength as we develop in our youth and similarly these factors diminish in our dementia (See tables 1 and 2) (Dick, 2003, pp.29-30). Our environment constantly changes, with changes in temperature, precipitation and lighting all affecting our perception. The objects with which we have to deal change in size, shape, velocity, changing our perspective and judgement.

> Every day, you move. This doesn't happen in a vacuum, though. Every movement you make occurs within the environment that surrounds you. You

> also move for a purpose - the tasks you perform have specific requirements. The way you move now has changed a great deal from your earliest movements, and will keep changing throughout your life. This is the essence of the study of motor development
>
> (Haywood & Getchell 2005, page x).

The fundamental nature of these effects are brought home to us by old age or by injury, when an assumed skill, learned half a century earlier, becomes impossible as a result of infirmity or a head injury. A task as simple as walking can become a problem when the surface on which we are walking changes.

> Our arms and legs move in different and distinct ways when we walk on a concrete sidewalk and when we walk on an icy sidewalk - or on a sandy beach. However, although the actual movements may differ, the motor skill we perform in each of these different situations is walking.
>
> (Magill, 2003, p.4).

These quotations highlight the complexity of human movement and the importance of the calculations being made in the brain in order to walk from one surface to another, to move from concrete to sandy beach. Anybody who has read a biomechanics book knows the high level of mathematics involved in making these calculations. By the age of five, most boys in the U.K. have started playing football and cricket and most girls have started playing netball and rounders. In football the players are required to run, dribble, pass, tackle, shoot and head the ball and interact with twenty one other players, a ball and a referee. In cricket one has to be able to bat, bowl and field. Bowling requires you to run up and "throw" a ball twenty two yards so that it lands in the same small area every time. To field requires you to be able to run and catch a ball before it lands or chase it and stop it before it goes over the boundary. To bat requires you to assess the speed, direction, spin and movement in the air of a small ball coming towards you at great speed and strike it with a cricket bat. The levels of skill required in netball and rounders are broadly the same as football and cricket. In five years the child has made substantial progress in his or her movement skills. It is at about this time, at the child reaches five years of age, that parents and teachers start to notice the differing movement skills of children (Macintyre, 2001, p.13). As they begin to leave the family where they have been playing with siblings older and younger than themselves who may well possess similar movement skills as they do, they go to school where they are thrown into open competition with all the other children in the area. This is the age when the most children are sent for specialist movement assessment (Macintyre, 2001, p.13). Individual difference factors that can contribute to differences in people's movement are:

- Abilities
- Attitudes
- Body type
- Cultural background
- Emotional makeup
- Fitness level
- Learning style
- Maturational level
- Motivational level

- Previous social experiences
- Prior movement experiences

(Schmidt & Wrisberg 2000, p.27)

Children between the ages of five and eight years develop their own perception of themselves and their place in society (Macintyre, 2001, pp.83-85). They form views on their appearance, intelligence and abilities (Macintyre, 2001, pp.83-85). Those who are unable to control their movements in class and who have become the butt of jokes for their "clumsiness" and who are unable to impress with their skills in playground games will suffer in terms of self-esteem and begin to seek ways of avoiding embarrassment, and these strategies usually include avoiding sport and games (Macintyre, 2002), often claiming that they are, "Too rough, boring or too tiring" (Geuze 2007, p.14). Human babies are born very small, very weak, out-of-proportion and unable to move in any controlled or planned manner. If they are to play organised games with their friends by the age of five they clearly need to grow taller, heavier, and stronger and to learn a number of movement skills. If they want to continue to play football and cricket into secondary school they will have to maintain these skills at the same time as their bodies are changing in size, strength and proportion and as they are learning new, more advanced skills.

> The motor systems of the brain exist to translate thought, sensation, and emotion into movement ....Movement is the end product of a number of control systems that interact extensively. Their complexity demands that we proceed logically by (1)defining the nature of movement in terms of muscles and joints, (2)presenting an outline of the motor systems so that the relation of the parts to

the whole is apparent from the outset, and (3) explaining how "control" is achieved.

(Cooper & Glassow, 1976, p.59).

Three body systems that are the primary components of the human motor mechanism were discussed in preceding chapters. To summarize with extreme brevity, movement initiated within the body was said to require first that nerve impulses reach muscle fibers. In the fibers the impulses start a chemical reaction that results in contraction of the fibers. As the muscle shortens during contraction, it tends to pull its bony attachments toward each other. The moving bones act as levers, transmitting energy from the muscle to a body part or an external object.

(Cooper & Glassow, 1976, p.111).

This discussion has set out the complexity of Movement Science. This dissertation does not propose to explore the subject to the limits of modern Movement Science, but rather to set out the complexity of the problem and the fact that it is a relatively new subject for research and that comparatively little is known about how it works, and that there is a great deal of scope for things to go wrong as is clearly the case in children with movement difficulties. Landmarks of achievement in movement skills have been identified for babies and children until they reach the age of twelve years, which is about the average age at which they undergo puberty and reach young adulthood. The areas of achievement considered include:

- Fine motor control
- Gross motor control
- Speech language skills
- Cognitive/perceptual skills
- Perceptual/ social skills

(Kurtz, 2008, pp.18-22)

These landmarks are set out in full in Table 3. Tracking of a child's performance in movement skills against these landmarks permits an assessment of his or her movement skills. Between 30% and 60% of the time at school in spent in attempting to achieve activities involving fine motor skills (Henderson & Barnett, 1998, p.35).

In order to further understand human movement and the movement difficulties experienced by children it is useful to have an understanding of the groupings of abilities used by Movement Scientists:

2.3: Definition of D.C.D.

There are a considerable number of definitions used to define D.C.D. The most authoritative and widely-accepted definition is published by the American Psychiatric Association (A.P.A.) in the most recent version of their Handbook, DSM-IV (see Appendix 3 for full text).

> The essential feature of D.C.D. is a marked impairment in the development of motor coordination (Criterion A). The diagnosis is made only if this impairment significantly interferes with academic achievement or activities of

daily living (Criterion B). The diagnosis is made if the coordination difficulties are not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and the criteria are not met for Pervasive Developmental Disorder (Criterion C). If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it (Criterion D).

(American Psychiatric Association, 2000, p.58)

However, the lack of a universal acceptance of this definition is revealed by Maureen Boon in her book, "Helping Children with Dyspraxia" which compares and contrasts various definitions of D.C.D. and Dyspraxia published or solicited, by her (Boon, 2002, p.7). These definitions are set out here as they highlight some of the most important issues surrounding children's movement difficulties. Unfortunately, they also illustrate the lack of knowledge and consensus on the subject.

The Dyspraxia Foundation (1998) defines dyspraxia as 'an impairment or immaturity of the organisation of movement. Associated with this there may be problems of language, perception and thought.'

Portwood defines dyspraxia as 'motor difficulties caused by perceptual problems, especially visual-motor and kinaesthetic motor difficulties' (Portwood, 1996, p.15).

McKinlay says, 'Dyspraxia is a delay or disorder of the planning and/or execution complex movements. It may be developmental - part of a child's make-up - or it can be acquired at any stage in life as the result brain illness or injury' (McKinlay 1998, p.9).

A Physiotherapist's Definition "Children with dyspraxia should demonstrate no hard neurological signs (i.e. damage of the central nervous system). Their motor performance should be at a level lower than that expected of their general learning abilities; i.e. their motor performance is out of step with their intellectual functioning."

Another Physiotherapist's Definition: D.C.D. is an umbrella term range of movement disorders that is not due to any obvious neurological or orthopaedic condition. There may be associated difficulties with social skills, attention control, self-help skills and perceptual skills.

Dyspraxia is a specific movement disorder characterised by difficulty in performing an unlearned complex motor skill that may be due to difficulty with ideation, or motor planning and sequencing or the execution of the task. The disorder is often associated with poor visual or auditory and/or kinaesthetic perception.

An Occupational Therapist's Definition

Children with dyspraxia have motor co-ordination problems. They often present as having problems with the organisation and execution of gross and fine movement. They often have associated difficulties with perceptual and organisational skills and may have receptive and expressive language problems.

> A Speech and Language Therapist's Definition 'Dyspraxia' is a term used to describe a motor problem that causes difficulty with initiation and/or sequencing of the muscle movements required to produce voice and/or speech. It is essentially a problem of not being able voluntarily to carry out movements that can easily be carried out involuntarily. A child may not be able to control and sequence breathing and voice and so only produce random vocalisations. He may not be able to move his tongue and lips into the correct positions or sequence of positions to make sounds, words or sentences, even though there is no muscle weakness to prevent this. A child can be observed to be licking his lips without realising whilst playing, but put on the spot and asked to lick his lips he cannot do so. Children who have the range of difficulties associated with dyspraxia often experience social-communication problems and difficulty in understanding the more abstract and subtle parts of language.
>
> A Teacher's Definition. Dyspraxia is a movement disorder not caused by a known clinical condition. The children affected are within the normal range of intellectual functioning and have poor hand-eye co-ordination and poor gross motor co-ordination. It can also affect speech."
>
> (Boon, 2002, p.7)

These definitions, taken together, show a general acceptance among a wide range of specialists that the condition exists. They set out the range of the difficulties associated with the condition, but fail to set clear delimiters on the problems. It is interesting to note the range of opinions both inter-and intra-specialism. Some of these experts believe the disorder to be developmental whilst others feel that it may be acquired later in life (Colley, 2006). There is a widely held view that the condition is linked to the organisation of movement, with some specialists relating it to ideation, planning, sequencing or execution (Cermak, 1985; Conrad, Cermak & Drake, 1983). Some relate the disorder to problems with sensory performance (Ayres, 1980; Hulme Biggerstaff, Moran & McKinley, 1982; Larkin & Hoare, 1991; Laszlo & Bairstow 1983; Laszlo, Bairstow & Bartrip, 1988; Willoughby & Polatajko 1995; Wilson & McKenzie 1998). The simplest and most straightforward definition for D.C.D. and the one employed in this dissertation in view of the fact that it deals with abstract rather than specific cases and that judgements on need are therefore impossible, is:

> Poor motor performance in daily activities that is not consistent with the child's age and intelligence and is not due to a medical condition
>
> (Geuze, 2007, p.10).

2.4: Types of D.C.D.

Recognising the heterogeneity of D.C.D., several authors have attempted to differentiate between various types of the condition. The majority of these have relied on an empirical approach and attempted to identify similarities on test scores (Henderson and Barnett, 1998). Another group have relied on a clinical inferential approach and based their decisions on clinical observations (David, Deuel, Ferry, Gascon, Golden, Rapin, Rosenberger, & Shaywitz, 1981; Deuel, 1992). A third group have attempted to apply a process orientated approach and based their discrimination on kinematic analysis of movement performance (Schoemaker, Smits - Engelsman, & Kalverboer, 1998). This concept of identifying various types of

D.C.D. may prove useful if it diminishes the expectation that a single universal cause and intervention may be discovered for D.C.D. and instead focuses attention onto several different causes that each requires a separate intervention that needs to be identified. At least one author has taken this a step further and actually labelled each of the statistical clusters that he identified:

- Verbal (Articulatory) Dyspraxia
- Oral Dyspraxia
- Occulomotor Dyspraxia
- Ideomotor Dyspraxia
- Ideational Dyspraxia
- Constructional Dyspraxia
- Dressing Dyspraxia
- Sensory integrative dysfunction

(Boon, 2002, p.11)

2.5: Causes of D.C.D.

In the absence of a clear definition for D.C.D., it is essential to have the best possible understanding of the causes of the disorder. Only in this way will it be possible to postulate on the possibilities for preventing the disorder and the ways in which children with movement difficulties can best be helped. As the majority of books on the subject of D.C.D. have been written by educationalists and medical therapists, or are of the self-help variety, their authors are not qualified to comment on the causes of a condition which is generally accepted to be of a neurological nature and they have refrained from doing so. Orton, who wrote the first medical paper on movement difficulties in children, was, on the other hand, a Consultant Neurologist. Orton claimed that the condition was likely to be caused by lesions in the brain and compared the observed symptoms of the disorder that he identified in children with the symptoms of an adult with an acquired apraxia in later life. He hypothesised that a unilateral brain lesion affecting the dominant hemisphere of the brain would affect the highly skilled movements and language skills that he had observed to be troubling the children. This lesion would therefore reduce the movement skills on the dominant side of the body and reduce the affected person to a state of being "doubly left-handed" as he described it. (Orton, 1937, p.120). The condition was presumably not considered sufficiently serious so as to ethically justify surgery on an experimentally-significant population of those with the condition and the state of technology in the early 20th century did not allow for scanners of sufficient quality to verify Orton's views, which therefore remained unconfirmed.

The second paper on children's movement difficulties was published in 1962 (*British Medical Journal*, 1962). The author reviewed the published work of three groups of researchers into movement difficulties in children, from Uppsala in Sweden, from Groningen in the Netherlands and from Newcastle-upon-Tyne in England, attended a conference on Minimal Cerebral Palsy in Oxford and then linked all this to his own experience and research. In his attempts to understand his findings and whether the symptoms related to the same condition or different conditions, he observed that the Swedish children were suffering from delayed development and appeared to catch up given time, accepted that the Dutch children's problems had been caused by anoxia and poor condition at birth and in the case of the English children specified that the disorder was not due to any disease or damage to the pyramidal, extrapyramidal or cerebellar pathways of the brain and after noting the similarities of the condition with those of children with lesions on the brain, accepted this as the cause, thus supporting Orton's views on at least one cause of movement difficulties in children. The conference he attended was organised by the National Spastic Society in Oxford, where consideration was given to the view that some clumsy children were afflicted with a form of minimal cerebral palsy and the author appears to accept that this may explain the symptoms of some children with movement difficulties.

The view that D.C.D. is a form of borderline or minimal cerebral palsy has been widely accepted by several subsequent authors (Hadders-Algra, 2003) without any further research or comment and with both conditions sharing the same characteristic symptoms of abnormal muscle tone, reflexes, motor development and co-ordination, it is easy to understand this popular view. It is particularly interesting that the incidence of cerebral palsy has been strongly linked to anoxia at or about the time of birth or during pregnancy (N.H.S., 2009) so that two of the four sources referred to in the B.M.J. article had suggested anoxia as a factor in the incidence of D.C.D., albeit one doing so indirectly.

Support for the view that difficulties during pregnancy, particularly at or around the time of birth and quite possibly linked with anoxia, may be associated with movement disorders in children, came in 1992 when three scientists published research although no cause for this synchronicity of opinion has been identified. A study of 135 children diagnosed as 'learning disabled' and therefore not simply affected by movement disorders, were found to have suffered birth trauma including premature birth, precipitate birth, late delivery, forceps delivery, caesarean section, breech delivery, foetal anoxia and induced labour (Cottrell, 1992). Birth trauma could cause the baby to be deprived of oxygen and therefore support the earlier research or it may be that the trauma is a symptom of the condition rather than a cause of it and further research is clearly required. Another researcher, Farnham-Diggory, suggested that a large number of minor abnormalities, such as immature brain cells or congenital tumours, occurred during pre-natal development and that the body compensates for these problems by re-wiring around them and that this unique re-wiring may cause the difficulties experienced in movement skills (Farnham-Diggory, 1992). Other research suggested that some children may have retained some primitive reflexes that cause shrugging, twitching, fidgeting and many of the symptoms of dyspraxia (Blythe, 1992). This could have the effect of sending a signal intended for one limb to all four limbs so that they receive four times their anticipated number of messages become confused and make mistakes and on occasion not realise that they had received an incorrect message the limbs start to react before cancelling the movement, giving the impression of fidgeting.

Since 1992 many researchers (Dyspraxia Foundation, 1998; Portwood, 1998 pp. 5 & 11; Rosenthal & McCabe, 1999, p.3) have speculated that the condition is not caused by any damage to the brain and have generally accepted that the disorder is related to a lack of maturity resulting in a lack of neural links in the brain (Portwood, 1998), although there has never been any scientific evidence to support this view. Recently published research (Flouris, Faught, Hay & Cairney, 2005; Hadders-Algra, 2003) has shown that the disorder is linked to the presence of lesions on the brain, which have only recently been identified as a result in advances in scanner technology.

2.6: Research into the Causes of Dyslexia

Research into D.C.D. has failed to identify factors relating to the incidence of the condition and little other than speculation exists that may assist future research and in such circumstances the best solution may be a sideways glance at similar areas of study. Dyslexia has always been linked to D.C.D. Both conditions were defined at the same time, both are specific learning disorders and they share many signs and symptoms. Unlike D.C.D. a great deal of research has been undertaken into the causes of Dyslexia. The similarities between the two conditions are striking when considering a definition for dyslexia employed to introduce a paper on the subject.

> Developmental **dyslexia** refers to a neurodevelopmental syndrome with a constitutional basis, defined by specific difficulties in learning to **read and write**, diagnosed when the achievement in these domains falls substantially below the level expected for the subject's age, intelligence and education (American Psychiatric Association, 2000). Dyslexia affects between 5% and 10% of the population, and is more common in males than females (Miles, 1993; Shaywitz, 1998). It also involves more than just **reading** difficulties and associated impairments. Other core features include:
>
> - abnormalities in visual and auditory processing (Stein, 2001; Talcott, Witton, Hebb, Stoodley, Westwood, France, Hansen, & Stein, 2002; Wright, Bowen & Zecker, 2000).
> - motor coordination difficulties (Nicolson, Fawcett & Dean, 2001)
> - problems with orientation, direction & sequencing (Miles, 1993)
> - a particularly uneven profile of cognitive strengths and weaknesses."
>
> (Cyhlarova, Bell, Dick, MacKinlay, Stein & Richardson, 2007, p.116)

When the word 'dyslexia' is replaced by the word 'dyspraxia' and references to 'reading and writing' are replaced with 'move', the only possible dispute is in the first of the listed core features. Whereas dyspraxia is often perceived as an "inconvenience" in that the children with the condition are a nuisance and knock over the furniture and disturb the classroom, dyslexia is considered a more serious problem affecting academic achievement. The Code of Practice for Special Educational Needs, issued by the Department of Education and Science, (Department for Education, 1994). suggests that children with Dyslexia may require some, or all, of the following:

- flexible teaching arrangements
- help with processing language, memory and reasoning skills
- help and support in acquiring literacy skills
- help in organising and coordinating spoken and written English to aid cognition
- help with sequencing and organisational skills
- help with problem solving and developing concepts
- programmes to aid improvement of fine and motor competencies
- support in the use of technical terms and abstract ideas
- help in understanding ideas, concepts and experiences when information cannot be gained through first hand sensory or physical experiences.

This indicates that learning skills are impaired and that academic success and employment opportunities for children with Dyslexia, will be affected.

The very same research paper that assisted in linking dyslexia and dyspraxia also identifies a clear link between deficiencies in fatty acids and the incidence of dyslexia.

> Increasing evidence implicates functional deficiencies or imbalances of omega-3 and omega-6 fatty acids in dyslexia............Omega-3 and omega-6 HUFA are crucial for normal brain development and function, and are recognized as essential nutrients because they cannot be synthesized de novo in sufficient quantity, and must be delivered pre-formed from dietary sources (Yehuda, Rabinovitz and Mostofsky, 1999; Uauy, Hoffman, Peirano, Birch and Birch, 2001)
>
> (Cyhlarova, Bell, Dick, MacKinlay, Stein & Richardson, 2007, p.117)

Children when reading require good orthographic and phonological skills to identify the characters and sound out the words that they see written on the page, but they also need the magnocellular area of the brain to be working efficiently to see what is written on the page. Those children with dyslexia appear to experience difficulties in the magnocellular system. The magnocellular system is the part of the brain which measures time, distance and motion. It identifies and measures movements, including those of the head, which it is then able to balance out so that it effectively stabilises images viewed by the child (Stein, 2003, p.1786). In dyslexic children that stability is lacking and the child's brain sees a blurred image on a page and in some cases may even see the words moving about on the page (Stein, 2003, p.1786). These effects, separately and combined, make it very difficult for the child to read. It is very easy to understand how difficulties in the part of the brain that measures time, distance and motion could affect movement skills and cause children to suffer from D.C.D. When the brains of those with dyslexia were surgically removed, post mortem, and compared with brains from control samples, it was found that the magnocells in the dyslexic brains were 30% smaller and significantly more disorganised than in the control brains. Consistent with this they recorded reduced and delayed averaged evoked potentials in response to a visual motion stimulus in alive dyslexics (Lehmkuhle & Williams, 1993; Livingstone, Rosen, Drislane & Galaburda, 1991) although the results have been disputed (Victor, Conte, Burton & Nass, 1993).

Children with dyslexia also experience difficulties with their phonological skills that allows them to understand the sounds that certain letters and combinations of letters make.

> The difficulties that dyslexic subjects have with phonological decoding are well demonstrated in tasks of nonword reading. Nonwords (for example, 'tegwop') can be correctly read only by applying the relevant grapheme-phoneme correspondence rules. Such tasks can discriminate good readers from poor readers
>
> (Witton, Talcott, Hansen, Richardson, Griffiths, Rees,...& Green, 1998, p.791).

Phonological skills have no apparent effect on movement skills and will be passed over quickly here, but the fact that dyslexia is caused by a combination of two factors, may assist to explain the causes of dyspraxia and the reasons why it has proved so difficult to understand. Clearly, the magnocellular system may be a factor in the incidence of dyspraxia but if it was the only factor then every child with dyslexia would also have dyspraxia. Phonological skills do not relate to movement skills and if it related to dyspraxia then every child with dyslexia would also have dyspraxia. It would therefore be reasonable to assume that there is a second factor in the incidence of dyspraxia, but that it has not yet been identified. The fact that there are two factors and that both were required to be present for dyspraxia to occur goes some way to explain the difficulties that have been experienced in identifying the cause of dyspraxia.

There is a theory is neurodevelopmental science that during their normal development children produce more brain cells than they need. Later, as the child develops, between 15 and 85% of the brain cells produced are destroyed by the body in a remodelling and rationalisation process. The neuronal links between these brain cells will be lost at the same time as the cells themselves are destroyed. The theory proposes that although the final number of brain cells conforms to certain rules and varies little from child to child, the size of each functional area of the brain may vary at this time from child-to-child (Kirby & Drew 2003, p.18). This would clearly result in affected children being advantaged and disadvantaged in various abilities and functions and may explain a lack of magnocellular cells in certain children.

In summary, research into the causes of D.C.D. can be characterised as being at a very early stage. Research has shown a link between the incidence of lesions in the brain and the incidence of D.C.D. (Geuze, 2007) and there is speculation that anoxia in pregnancy particularly at or around the time of birth and trauma at birth may be factors (Cottrell, 1992) but there is little reliable research to support any of this. The similarities between dyslexia and dyspraxia appear to provide the strongest basis for finding a cause for the disorder, with a lack of fatty acids during pregnancy (Cyhlarova, Bell, Dick, MacKinlay, Stein & Richardson, 2007, p.117), and a reduction in the size and number of magnocellular cells requiring further investigation (Stein, 2003, p.1786). None of this, however, suggests a viable intervention likely to be effective in reducing the incidence or symptoms of the condition, other than fatty acid supplementation, and it appears likely that the best intervention may have to come from among methods of improving skills in the general population.

2.7: Symptoms of D.C.D.

> Underlying deficits have been shown to involve perceptual factors (Hulme et al., 1982; Hulme, Smart & Moran, 1982; Hulme et al, 1984; Laszlo & Bairstow, 1985; Laszlo, Bairstow & Bartrip, 1988; Lord & Hulme, 1987a; 1987b; 1988), speed of decision making (Rosblad & von Hofsten, 1994; Smyth & Glencross, 1986; van Dellen & Geuze, 1990; van der Meulen, Denier van der Gon, Geilen, Gooskens & Willemse, 1991), and feedback and motor programming differences (Lord & Hulme, 1988; Smyth & Glencross, 1986).
>
> (Sugden & Chambers, 2003, p.32)

Self-help books written by those with D.C.D., and their helpers, provide important anecdotal evidence of living with the disorder and its consequences and set out a complex web of primary and secondary symptoms of the condition that when combined with the overlap between D.C.D. and other specific learning disorders, and the division into the various different types of D.C.D., make it very difficult to isolate the essential symptoms of the condition, thus making defining, diagnosing and treating the disorder very difficult. The secondary symptoms have been investigated by a number of researchers in order that their effects may be fully understood and in this way peeled away leaving simply the primary symptoms of the disorder. David Sugden, the father of research into movement disorders in children in the U.K. and co-author of the Movement A.B.C. test, which is widely used in the U.K., provides a summary of the secondary symptoms:

> Apart from the movement difficulties seen in children with D.C.D., there is evidence that in comparison to non-D.C.D. children, the disorder is accompanied by social and emotional difficulties, such as behaviour problems (Losse, Henderson, Elliman, Hall, Knight & Jongmans, 1991), low self-esteem (Shaw, Levine, &Belfer, 1982) poor goal setting, low self-concept with a reduced inclination to accept responsibility (Henderson, May & Umney, 1989) isolation, lack of self-confidence, being teased (Kalverboer, De Vries,& Van Dellen, 1990) and poor social competence (Kalverboer et al., 1990; Knight, Henderson, Losse, & Jongmans, 1990). The long-term prognosis for these children is not good in general, although some children do catch up with their peers (Cantell, Smyth &Ahonen, 1994; Geuze & Börger, 1993; Losse et al, 1991; Lyytinen & Ahonen, 1989).
>
> (Sugden & Wright, 1998, p.43)

This summary clearly sets out the serious nature of D.C.D. and the effect that the disorder has upon the psychological, behavioural and social conduct of the affected children and its likely effects on the children's performance and achievement in life. Clearly, these factors obscure all but the physical aspects of the condition so that all research into the primary symptoms of the disorder must focus on the physical aspects and ignore all other aspects. A number of authors have attempted to define a list of primary symptoms that would assist with the diagnosis of the condition and the identification of suitable interventions to assist in dealing with it.

- Movement
- Language
- Eye movements
- Perception
- Thought
- Specific learning difficulty
- Personality and behaviour
- Variability

(Ball, 2002, p.14)

- Gross motor skills
- Fine motor skills
- Speech and language
- Social skills
- Attention and concentration

- Learning
- Visual motor skills

(Boon, 2002, p.14)

Consideration could, perhaps, have been given to including psychological, behavioural and social conduct in the list of secondary symptoms, such as social skills, attention and concentration, personality and behaviour and learning. It is a simple matter to realise that a child who experiences difficulty in controlling his or her movements may be tempted to isolate him or herself rather than face direct comparison with another child, lose concentration and then misbehave in order to secure an adult's attention and as a result may not learn well. D.C.D. is a specific learning disorder and, as has been set out previously, it overlaps considerably with other specific learning disorders so little is added to the debate by setting down social skills, attention and concentration, personality and behaviour and learning as symptoms. Similarly, thought processes are difficult to assess and likely to be affected by the secondary symptoms so when these issues are disregarded the symptoms agreed by both authors are:

- Movement
  - Gross motor skills
  - Fine motor skills
- Visual motor skills
  - Eye movements
  - Perception
- Speech and language

The symptoms may affect the child in a variety of ways, from simply causing them to knock over the furniture in class to the most severe cases where the child's problems relating to speech, language and voice skills are so severe as to affect his or her breathing. This may be related to the identified problems in controlling movements of the lips, tongue and mouth.

Interestingly, only one author, Mary Colley has related any positive effects from D.C.D. (Colley, 2006). The theory that brain cells are allocated to tasks and that some are destroyed during a child's development would clearly indicate that a deficiency in one area was compensated by a strength in another area. It is also likely that having to deal with a problem is likely to develop a strength. It has been suggested that those with D.C.D. are "creative, determined, original and hard-working" possessing "strategic-thinking and problem-solving skills" and this might be explained by the constant need to invent excuses for knocking over the furniture, to try to stop doing it again and struggling to control movements to avoid the problem if all else fails. They can also be very caring and intuitive, whilst some have become gifted writers, such as Victoria Biggs author of the book 'Caged in Chaos' (Biggs, 2005).

Anecdotal evidence suggests that the symptoms of D.C.D. start shortly after conception. Expectant mothers have related that babies in the sixth week of pregnancy, who later experience movement difficulties in childhood, have been identified by their lack of movement in the womb at this time (Kirby & Drew, 2003, p.20), so these problems may occur very early in our development, but this requires further research in order to confirm it. Symptoms have also been said to develop later in life, such that the condition could be labelled 'Acquired' as well as 'Developmental' (Colley, 2006, p.15).

The symptoms of D.C.D. diminish as the child ages and develops, but they persist into adolescence (Cantell, Smyth & Ahonen, 1994; Geuze & Borger, 1993; Visser, 1998; Visser, Geuze & Kalvaboer, 1998) and even into adulthood (Cousins & Smyth, 1994; Cousins & Smyth, 2003; Kirby & Drew, 2003) The child simply learns coping strategies to deal with them, such as avoiding P.E. classes or growing up and leaving school so that they are not required to take part in sporting activities.

2.8: Is D.C.D. a new problem?

The question arises as to whether D.C.D. is a new condition or whether it has always existed and has only recently been identified, possibly as a result of an increasingly formal education highlighting clumsy accidents or by increasing awareness by trained teachers. This question is raised by Brookes, in his book, 'Dyspraxia', in which he expresses the view that "it has existed for as long as the brain has been operating" but failing to supply any evidence to support this view (Brookes, 2007a). The truth is likely to be somewhere between the two extremes, with the condition existing in some form but being aggravated by modern nutrition and inactivity and being more easily identified with advanced teaching in more confined and better-disciplined classrooms.

2.9: Diagnostic Testing for D.C.D.

David Sugden, the author of the best recognised test for D.C.D. in the U.K. accepts that most primary school teachers can name those of his or her students with the condition after just a short time of working with them in class (Sugden & Wright 1998, p.53). However, a recognised condition with which children may be diagnosed and for which they may be seeking an intervention, and into which further research is required, much of it funded, requires a recognised and formal test to identify it. Hence as soon as the problem with children's movement skills had been identified, terms such as D.C.D. had been agreed and a definition of the condition accepted, there was an urgent need to put in place a test to diagnose the condition. In the surge of activity that followed the B.M.J. paper entitled 'Clumsy Children' in 1962 and the numerous papers of Ayres in the U.S.A in the late 1960s, research scientists focussed their efforts and attention on specifying a test to detect children with D.C.D.

As nobody dies from movement skills difficulties and the problems associated with the disorder are highlighted particularly in those places with small, well-furnished and well-equipped classrooms and highly-disciplined educational systems, it tends to be the more advanced, western countries that take movement skills disorders seriously. The majority of research into D.C.D. is conducted in countries such as the United States, Canada, Australia, the United Kingdom and the Scandinavian Countries. Each group of researchers sought a test that would satisfy the minimum requirements for all scientific tests, those of reliability and validity. As their research continued the less essential but nevertheless desirable attributes of speed, cost, convenience, portability, simplicity, universal application, requiring few facilities and little equipment, and little staff training, became priorities.

A number of tests have been designed in order to identify those children with movement skills problems. These include:

- Denver Developmental Screening Test (Frankenburg & Dodds, 1967; Frankenburg et al, 1990)
- Bayley Scales of Infant Development (Bayley, 1969)
- Peabody Developmental Motor Scales. (Folio & Fewell, 2000)
- Schedule of Growing Skills II (Bellman et al, 1996)
- Purdue Perceptual Motor Survey (Roach & Kephart ,1966)
- Bruininks-Oseretsky Test of Motor Proficiency (Bruininks, 1978)
- Fundamental Movement Pattern Assessment Instrument (McClenaghan, 1976; McClenaghan and Gallahue, 1978; Gallahue and Ozmun, 1995)
- Developmental Sequence of Fundamental Motor Skills Inventory (Seefeldt & Haubenstricker 1976; Haubenstricker, Seefeldt, Fountain & Sapp, 1981)
- Test of Gross Motor Development (Ulrich, 1985)
- Ohio State University Scale of Intra-Gross Motor Assessment. (Loovis & Ersing, 1976)
- Basic Motor Ability Tests - Revised (Arnheim & Sinclair, 1979)
- Movement ABC Battery for Children (Henderson & Sugden, 1992)
- Pediatric Evaluation of Disability Inventory (PEDI) (Haley, Coster, Ludlow, Haltiwanger, & Andrellos, 1992)

- The School Function Assessment (Coster, Deeney, Haltiwanger & Haley, 1998)
- Ecological Task Analysis. (Davis & Burton, 1991)
- Examination of the Child with Minor Neurological Dysfunction (Touwen, 1979)
- Kinaesthetics and Sensitivity Test (Laszlo & Bairstow, 1985)
- The Abilities of Young Children Test (Griffiths, 1970)
- Southern California Sensory Integration Test (Ayres, 1972)

(Kirby & Drew, 2003, p. 57-58)

With so many tests it was essential to compare and contrast the results that they generated and this was initially done in 1982 by Jack Keogh. He came to the conclusion that "there is very little agreement within and across studies in the identification of clumsy children" (Keogh 1982, p. 247). In 1992 researchers compared the results generated by three popular methods of testing children's movement skills, the Test of Motor Proficiency, the Test of Motor Impairment and the judgement of teachers found that each procedure identified a different set of children as poorly coordinated (Maeland, 1992). Later, in 2001, a comparison of the two most popular tests, the Movement A.B.C. Test favoured in the U.K. and the Bruininks Oseretsky Test favoured in the U.S., found significant differences in the results and a co-incidence factor of only 0.80 that neither test was better than the other, but rather that the best results were achieved by undertaking both tests (Crawford, Wilson & Dewey, 2001).

Details of these tests were then published in peer-reviewed journals so as to permit the researchers to evaluate each others findings and select the best test. Unfortunately, instead of agreeing on a common test, each country decided to use their own test, and where different tests are performed different results usually follow, leaving doubts as to the reliability and validity of the testing. Research to compare the test results have shown significantly different results with the consequence that some children will always be missing out on the treatment and support that they require. The Movement ABC Test is widely used in Europe, Southeast Asia, and Australia, although it is not as common in the United States where the Bruininks-Oseretsky Test of Motor Proficiency is widely used (Sugden & Wright, 1998).

Once a concensus had been reached relating to the testing methods, then testing kits needed to be produced so that the same equipment could be used at each of the centres performing the testing. Each group of researchers approached commercial partners and arranged marketing deals whereby the testing kits were made commercially available. Training courses were arranged so that teachers could be trained in the use of the testing kits, familiarise themselves with the equipment and protocols and discuss their experiences. Commercial interests reinforced the academic differences between the groups.

In the United Kingdom a Code of Practice was then established for the assessment of children with movement skills difficulties (see Table 10). The Code of Practice provided for communication between parents and teachers, referral to school Special

Education Needs Co-ordinators (S.E.N.C.O.'s) and professional assessment by an educational psychologist. Unfortunately, as the Code is a Department of Education document, parents are generally unaware of it unless they communicate with a teacher and therefore many parents, identifying movement skills difficulties in their child, take him or her to see their doctor, who then makes his or her own diagnosis in his or her own way. Clearly, the teaching and medical professions have vastly different areas of knowledge and expertise and few doctors have the training, experience or equipment necessary to carry out a Movement A.B.C. Test on a child brought to them by a concerned parent (Macintyre, 2000; Boon 2003). In order to understand this situation, it is necessary to consider the definition of D.C.D. from the American Psychiatric Association Diagnostic and Statistical Manual, which clearly requires four factors to be considered when assessing children for the purposes of diagnosis:

A. Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (e.g., walking, crawling, sitting), dropping things, "clumsiness," poor performance in sports, or poor handwriting.

B. The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living.

C. The disturbance is not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and does not meet criteria for a Pervasive Developmental Disorder.

D. If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it.

(American Psychiatric Association, 2000, p.58)

In practice, these criteria mean that when a child is assessed by a doctor, he or she will generally accept anecdotal evidence of movement skills problems from the parent. The doctor will however, have the clear ability to consider the incidence of any other medical condition which may be present. The requirement for the disorder to significantly affect academic achievement or the activities of daily living requires a subjective judgement and may result in variable results. The doctor performing the assessment is unlikely to have the opportunity to assess the one hundred children necessary to be able to statistically adjust his or her results. A teacher conducting an assessment will generally undertake a full and careful assessment using the Movement A.B.C. Test as set down in his or her training. The teacher's ability to consider alternative medical conditions must, of necessity, be limited when compared to that of the doctor. The teacher may also make a professional judgement on whether the disorder affects academic achievement or the activities of daily living, but may well have undertaken sufficient tests to be able to statistically adjust his or her results.

Discussions with those regularly performing assessments of children referred to them due to their movement skills difficulties indicate that a number of problems exist with the current testing arrangements. The cost of the Movement A.B.C. test kit at around £750 has meant that most County or London Boroughs have purchased just one kit, thereby limiting the potential number of tests to be performed and generally meaning that the kit remains with one assessor, thus reducing the opportunity for other assessors to gain the necessary knowledge and experience of using the kit. If the kit was cheaper then it should be possible for local authorities to purchase more kits and train more assessors and it may even be possible to encourage some schools to purchase their own kits and train their own assessors, with the possibility of universal screening taking place. The limited availability of the testing kits, together with the need for statutory assessments means that assessors have to visit schools for individual tests. Each Movement A.B.C. assessment takes half a working day to complete and when travelling time to the school, time spent meeting and greeting colleagues and making essential rooming arrangements and setting up and putting away the testing equipment is included then each test takes a full working day to complete and limits testing to a maximum of five children per week. With other responsibilities taken into consideration, it may well be less. Several authors have indicated that a number of additional tests are required for a full diagnosis with one group of experienced researchers recommending that the tests need to be repeated by class teachers, P.E. teachers, Special Educational specialists, speech and language therapists and others and in a wide range of settings whilst reading, writing , speaking, and other skills. (Ripley, Daines & Barrett, 1997, p16), which will, of course, considerably extend the time taken to complete the diagnosis.

The tests that form the Movement A.B.C. Test are sensitive to social, ethnic, gender and cultural factors which affect the results (Sugden & Wright 1998, p.53). The instructions accompanying the testing kit set down that the tests should not be practiced skills but rather a new activity outside of the child's experience, designed to test some raw skill. Indeed, the instructions generally call for the assessor to permit one practice attempt for each activity so as to allow the subject an opportunity to familiarise themselves with the activity and the equipment.

In summary, it has become clear that none of the tests are producing results that meet the minimum standards of reliability and validity. A number of tests exist and the results have been shown to vary from test-to-test. None of the tests are able to identify the severity or cause of the difficulties. The two leading tests, the Movement Assessment Battery for Children and the Bruininks-Oseretsky Test of Motor Proficiency have both been revised as a result of experience gained by practitioners, but none of the weaknesses listed above have been satisfactorily addressed and it is clearly time for a fundamental re-think rather than a quick fix. Two leading practitioners, Amanda Kirby and Sharon Drew have suggested a total re-think of the reasons why we assess and suggest that the following questions need to be addressed:

- What is the purpose of assessment?
- Is there a functional problem that is stopping the individual accessing activities of daily living, the curriculum or gaining a place in employment?
- How severe is the problem?
- What is the nature of the deficit?
- How will the assessment help the individual in accessing help/remediation or knowing where else to refer for further help? (Kirby & Drew, 2003, p.52)

They have also summarised a number of other methods of information gathering that have been described by practitioners attempting to seek information on the severity and nature of the disorders when attempting to identify the best intervention in each case:

- Parent interviews
- Parent questionnaires
- Teacher interviews
- Teacher questionnaires
- Child-centred questionnaires
- Work samples
- Systematic observations
- Information from other professionals such as previous reports
- Video
- Stills photography

(Kirby & Drew 2003, p.61)

Between 4 and 10% of all children are affected by movement skills disorders and 2% are seriously affected by them. Approximately four times as many boys as girls are affected, (Gordon & McKinley, 1980; Portwood, 1996) although where girls are affected the symptoms tend to be more serious. Most children with D.C.D. are also affected by some other syndrome, such as dyslexia, which affects half of all children affected by D.C.D.

Clearly, there is a need for a quick, cheap, simple and objective test capable of providing reliable and valid results. Such a test would encourage further research into the condition, support efforts to identify an effective intervention and assist in the identification of those with the condition.

2.10: Interventions for D.C.D.

> The primary objective of all methods of intervention for children with D.C.D. is to improve their motor skills and their ability to function in everyday life.
>
> (Sugden & Chambers, 2003, p.3)

There is no known cure for D.C.D. (Ball, 2002; Macintyre, 2001). The symptoms may be reduced and the child may learn coping strategies as they grow older, but the symptoms persist into adolescence (Cantell, Smythe & Ahonen, 1994;Geuze & Börger, 1993; Visser, 1998; Visser, Geuze & Kalvaboer, 1998) and even into adulthood (Cousins & Smyth, 1994; Cousins & Smyth, 2003; Kirby & Drew, 2003) The earlier that the condition the intervention started, the better for the child's prognosis (Missiuna, Rivard & Bartlett, (2003).

> Intervention approaches vary but can generally be grouped into two broad categories of process and task orientated approaches (Sugden & Chambers, 1998; Sugden & Wright, 1998). (Sugden & Chambers, 2003, p.3)

Experts from a wide variety of specialisms have applied their knowledge and experience to the problems of children with D.C.D., but those whose subjects are closest to the most serious problems facing children with D.C.D. are the neurodevelopmentalists and human movement scientists whose subjects are at a comparatively early stage of research and who have not, as yet, contributed to this topic. Those experts who have designed interventions have attempted to identify the cognitive processes with which the child struggles and the tasks which they find difficult and then arranged for these to be practiced at length. As Orton put it when he first identified the condition, "While the acquisition of skills is arduous for the apraxic, almost any technique can be mastered with sufficient application and practice" (Orton, 1937, p.193). It should also be noted that a wide range of alternative therapies have been applied, usually without any justification, in an attempt to find an intervention able to assist the children with the condition, but none have achieved success worthy of reporting. The therapies include:

- Aquatic Therapy
- Aromatherapy
- Auditory Training
- Brain Gym
- Craniosacral therapy
- Dance/ movement therapy
- Developmental optometry
- Interactive Metronome
- Myofascial release
- Therapeutic brushing (Wilbarger Protocol)
- Therapeutic massage
- Therapeutic riding (hippotherapy)
- Yoga

(Kurtz, 2008, p.63)

(More complete details of these efforts are set out in Table 11)

A problem also exists in identifying the appropriate person to assist children with D.C.D. In general, when the condition is identified by medical professionals then the child with the condition is referred to a physiotherapist or an occupational therapist who spends time with the child on a one-to-one basis practicing process and task orientated tasks in a manner in which each skill is "subdivided, instructed and rehearsed until it is mastered" (Addy 2006, p.17). When the condition is identified in an educational environment the same role is delegated to a physical education teacher (Sylvester, 1999; Williams, Smith & Ainsley, 1999). This practice takes up a considerable amount of staff time of the physiotherapists and teachers employed in performing this assessment, therefore costing a considerable amount, which makes it unpopular with managers, particularly during a financial crisis when costs are being tightly controlled (Kirby & Drew, 2003). As a result of their involvement in assisting children to practice, several physiotherapists, occupational therapists and physical education teachers have written books and papers on the subject of D.C.D. The majority of these books and papers have related to practicing the process and task oriented objectives, but the exception is written by physiotherapists who achieved a very substantial 72% improvement in children's movement skills by using strength training exercises with the children (Lee & Smith, 1998, p.276).

Lee and Smith are Superintendent Physiotherapists who were part of a London-wide initiative whereby Superintendent Physiotherapists came together to review the work that their departments were currently undertaking with children with D.C.D. The group decided that their priority should be to develop strength in the children and they focussed particularly on the children's leg and core muscles. Each child was assessed by a physiotherapist and an individual programme was designed for every child. Parents were taught how to supervise the session and it was arranged that each child would undertake daily training with a parent for between 15 and 20 minutes, except on the one day each week when the child would have a one hour session with the physiotherapist so that progress could be monitored and any problems resolved. The exercises selected involved the use of the child's bodyweight and the child started with ten repetitions and progression was reflected in an increase of five repetitions per exercise per week. The physiotherapists recorded a 72% average improvement in the children's movement skills after eight weeks, although it was noticed that in some cases where children were unable to attend for the final two weeks of the programme, progress was substantially less. The researchers also noted that several children started to lose enthusiasm for the programme towards the end. This may have been because of the rather restrained nature of a hospital physiotherapy department, where most of the patients are elderly and silence is the general rule. Participation in P.E. and Sport at school tends to be a little less restrained and with careful coaching it should be possible to maintain a more positive atmosphere. No opinion was expressed by the researchers for the reasons for the children's improvement in movement skills. This research has been discounted by some researchers (Sugden & Chambers, 1998) as being too expensive and requiring unreasonable amounts of professional time to be worthy of further investigation.

> Other factors that may contribute to the lower performance of children with D.C.D. is their lack of muscular strength, or the inability to exert maximal force, and their power, or the rate of performing work (Knuttgen and Komi 1992)...As such, the difficulties experienced by children with D.C.D. during these fundamental motor skills (Larkin and Hoare 1991) may be associated with strength and power deficits. Such a correlation between strength and power deficits and movement problems in children has been demonstrated by Damiano and co-workers (1995) who found the quadriceps strength and gait of children with CP improved following a 6-week strength-training programme. If strength and power are found to be deficient in children with D.C.D., a strength-training program may prove to be an important component of successful remediation programmes
>
> (Raynor, 2001, p.245).

Raynor confirmed the research findings of others, (Larkin, Hoare, Phillips & Smith, 1988; O'Beirne, Larkin & Cable, 1994; Raynor, 1989) that children with D.C.D. were less powerful than their peers without the condition and then went on to attempt to ascertain the reasons for this. She discovered increased levels of co-activation in the children with D.C.D. (and compared this to the work of Pfeiffer & Francis, 1986; Ramsay, Blimkie, Smith, Garner, MacDougall& Sale, 1990; Weltman, Janney, Rians, Strand, Berg, Tippitt, Wise, Cahill & Katch, 1986) that reported that effective muscle activation in the absence of muscle hypertrophy was one of the neural factors associated with increased muscle strength. Lack of strength, particularly in the hands and wrist has long been recognised by students of movement skills difficulties in children (Oliveira, Shim, Loss, Petersen, & Clark, 2006). Sheila Henderson, a prolific researcher in the subject for thirty years, has gone so far as to suggest a range of solutions for dealing with the problem of children with movement difficulties lacking in strength, without ever, apparently, proposing that steps be taken to improve their strength.

1. Lower the net or basketball goal.
2. Reduce the distance the ball must be thrown or served (a) between bases, (b) between serving line and net, or (c) between partners.
3. Reduce the weight and/or size of the ball or projectile. Balloons are lightest, medicine balls are heaviest.
4. Reduce the weight of the bat or striking implement. Shorten the length of the striking implement or choke up on the bat (i.e. hold the bat further down towards the striking surface instead of at the top).
5. Lower the centre of gravity. Games played in a lying or sitting position demand less fitness than those in a standing/running position.
6. Deflate air from the ball or select one that will not get away so fast in case the student misses a catch and has to chase the ball. (Wright & Sugden, 1999, p.22)

When a list of twenty four symptoms of D.C.D. compiled from a variety of sources is compared with the positive effects of strength training it becomes clear that each one of the symptoms is the reverse of the positive effects of strength training. It is very surprising that the outstanding results generated by the strength intervention of Smith and Lee were not followed up by other researchers, particularly perhaps by some of the substantial number of physical education teachers involved in working with the children with D.C.D.. One of the reasons for this failure to consider strength training as an intervention may be the extreme reluctance of the children affected to participate in physical education or sporting activities of any kind. Children with movement skills difficulties are embarrassed by their lack of skills when participating in P.E. lessons and very quickly decide that P.E. is not for them and devise a range of coping strategies that assist them to avoid all participation in sport. In fact, P.E. has been described as "one of the dyspraxic child's most challenging activities" (Boon, 2002, p.51). It is very easy to understand that the avoidance of participating in any sport will have a negative effect on each and all of the components of fitness including strength, endurance, muscular endurance, speed, flexibility and body composition, (Boon, 2002, p.59). Of course, when the children's health is high on the political agenda and when physical education teachers are required to teach health education and diet as well as sport itself, this could be argued to be the best reason for pursuing the children to participate more. The only researcher identified to have proposed the idea of training children with D.C.D. so as to improve their fitness and strength is Cartilege, a special education needs co-ordinator from Sussex, but his training sessions were very gentle when compared with the programme set down in this research and reported no improvements in muscular control and no reduction in the symptoms of children with D.C.D. (Cartilege, 1995).

This research will seek to use the results of the research undertaken by Lee and Smith in London and Raynor in Western Australia and attempt to identify a third way that uses their research to find a practical strength intervention that may be universally applied to children in class-size groups by class teachers and/ or P.E. teachers who are available at school at no additional cost and using equipment that is readily available at all schools. The sessions will take place twice per week and last no longer than thirty minutes, the time that most children are given for P.E. classes, when time for changing is deducted. Whilst agreeing with Raynor that the focus of the training should be the children's legs and trunk it will also look to find a way to strengthen fingers, hands and wrists which have been identified as a problem for children with D.C.D. (Oliveira, Shim, Loss, Petersen, & Clark, 2006). Kirby has proposed clear guidelines for reviewing interventions for those children with D.C.D. and these will be considered when preparing a suitable intervention.

Reviewing an Intervention

It is therefore important to analyse and critically reflect upon the claims made.

Some questions to consider are:

- What is the treatment?
- What are the claims?
- Who is making them?
- Professional body - what professional organisation does the person who is administering the 'treatment' belong to? What is their code of practice?
- What training have they undertaken?
- Risk - is there any risk to the individual in taking part?
- Indemnity - what has the company or individual in place in case of harm?

- How is the treatment supposed to work?
- What evidence is there for success? Is this anecdotal in nature?
- Who can be helped?
- Who cannot be helped?
- How long do you have to have the treatment for?
- Are there any side effects?
- What evidence is there to show the effects?
- If studies have been done - what size, how constructed, what are the long-term benefits, is there carry over, and how long does the individual have to continue treatment for?
- What is the cost of the treatment? (Kirby & Drew, 2003, p.167)

2.11: Children and strength

Strength is a primary component of fitness and essential for healthy living. (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004). A lack of strength, leading to imbalances in muscular strength, is a major cause of injury (Grace, 1985; Grace et al, 1984; Wang & Cochrane, 2001). Strength is improved by resistance training in people of all ages and resistance training is safe to perform, when undertaken sensibly and within the guidelines compared with other sports. (Hamill, 1994, p1; Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004, p.387)

> Muscular strength gains have been evident across all maturity stages including pre-pubescents (Rians et al., 1987; Blimkie et al., 1989; Ramsay et al., 1990; Faigenbaum et al., 1993), pubescents and post-pubescents (Pfeiffer and Francis, 1986).
>
> Retrospective surveys suggest lower injury rates compared to many other sports in the UK (1994) and US (Blimkie, 1993).
>
> (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004, p.387)

Recent changes in lifestyle have increased the desire among families for children to become stronger (Kraemer & Fleck, 1993, p.3). Increased opportunities to participate in competitive sport and an improved knowledge of sports science which has highlighted the value of strength training in improving sporting performance, have led to a desire for our children to become stronger (Kraemer & Fleck, 1993, p.3). An historic perception in the U.K. that strength training is inherently dangerous and should be avoided until majority is reached has recently been overcome. In 2004 the British Association of Sports and Exercise Sciences (B.A.S.E.S.) published a report produced by a committee of experts in medicine and sports science, chaired by Gareth Stratton of Liverpool John Moores University, in which the first recommendation was that "All young people should be encouraged to participate in safe and effective resistance exercise at least twice a week", whilst also recognising that resistance training may take many different forms. (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004). Recent research has indicated that children are currently not undertaking sufficient exercise to achieve satisfactory standards in any of the components of fitness, including strength and that their health is suffering as a consequence (W.H.O., 1992; Sandercock, Voss, McConnell, & Rayner, 2010).

The author's first daughter was born with a deformed and withered right leg. A visit to the local hospital raised the possibility of surgery to correct the problem, until the Consultant attended and identified that the deformity had been caused by the leg being trapped under the baby in the womb, so that it had not been exercised and had received a poor blood supply. The author was advised to stroke the leg in a certain way, so that the baby straightened the leg and pulled up the toes. The stroking provoked the baby to vigorously straighten the leg and ankle, which strengthen and developed the muscles involved. In two weeks the deformity had been corrected and the musculature of the leg restored to the normal range. It is never too young to undertake remedial physical therapy, based on resistance training.

Despite the research indicating that resistance training is not only safe but very important for the complete and balanced development of young people, a proposal to undertake research at schools focusing on resistance training for young children is unlikely to be well received by staff and parents, due to unfounded fears regarding the safety of resistance training. In addition this research aims to identify an intervention to reduce the symptoms of D.C.D. that is universally available to children with the condition, i.e. requiring no specialist equipment or training. The intervention aims to eliminate weakness rather than to build exceptional strength and an exercise programme involving running and jumping, such as described in the

Elevating Athletics programme published by U.K. Athletics (see Appendix 9) satisfies all these aims.

2.12: Entropy

Entropy uses a non-linear time series analysis method to track the movement of a subject's centre of gravity, along the three geometric axis, using a box of insignificant size and weight attached to a belt which can easily be attached to, and removed from, the subject using Velcro (Figure 2) (Arif, Ohtaki, Nagatomi & Inooka, 2003). Through the application of mathematics it is possible to combine the results obtained from each of the three axis, X, Y and Z, into an Entropy Score which can be used as a measure of smooth, controlled movement, with a lack of controlled movement indicating movement difficulties. Until recently, the technique has been used largely to assess walking stability among old people, usually focusing on those above 75 years of age who are likely to lack stability and more likely to fall and suffer serious, and possibly fatal, injury (Arif, Ohtaki, Nagatomi & Inooka, 2003; Khandoker, Palaniswami & Begg, 2008; Kurz & Stergiou 2003). This research will assess the application of the technique to children aged from 8 to 11 years in order to identify those with movement difficulties.

All subjects will be instructed to walk along a 40 metre straight hospital level walkway at a self-selected walking speed. Walking is a simple and practiced skill that will have been mastered by every child between the ages of 8 and 11 years unless they have been diagnosed with some disorder.

2.13: Summary

Although there is now an almost universal acceptance that some children suffer with movement difficulties, the nature of the condition is such that its symptoms are variable from child-to-child and in the same child from day-to-day and even from hour-to-hour, depending on the child's health and state of exhaustion. The cause of the condition has been the subject of considerable conjecture. A substantial number of tests have been designed to identify movement skills difficulties in children and although each of the countries in which attention is focused upon the condition have selected a preferred test, there is a considerable amount of further research necessary before a universally recognised test is identified. Research has confirmed that these tests each identify a different group of children as possessing the condition and requiring support and assistance. Each test requires expensive, specialist testing equipment and specially trained staff in order to perform the test. Each test takes time and effort to perform and provides subjective results that meet neither common standards for validity or reliability. No protocol exists for a common treatment that will assist the majority of those with the condition. Clearly, a great deal remains to be done.

This research seeks to assess the application of the principals of entropy in order to seek a universal, objective, valid and reliable test for movement difficulties in children. It will then consider a vigorous programme of exercise designed to improve the children's strength and fitness and consider its efficacy as a universal intervention that will improve the movement skills of the majority of those children with the condition. The programme will be based on explosive running, jumping and bounding, as these are activities which young children regularly undertake whilst also being sufficiently demanding to promote the necessary improvements in strength. The programme will last six weeks, in accordance with the principles of periodisation, which recognise that six weeks is the period needed in order to ensure improvements in strength.

Chapter 3: Methodology and General Methods

3.1: Methodology

Complex problems require a comprehensive analysis of the facts in order to identify the best solution. Only by experts from a wide variety of specialisms studying the problems can the facts be established and solutions identified. Fortunately, complex problems do not always require the application of the most complex or advanced science. This research proposes to consider all available research on D.C.D. in a thorough review of the literature and by re-assessing it to identify simple, practical solutions that may have been overlooked and which can then be investigated and evaluated.

(Orton, 1937) and a wide range of experts, mostly from the medical and teaching professions, have studied the problem of D.C.D. Remarkably few sports scientists and no sports coaches have published books or research papers on the subject. Most remarkably of all, recent books on the subject of human movement skills (Schmidt & Wrisberg, 2000) and human movement development (Haywood & Getchell, 2005) make no mention of children's movement difficulties, clumsy children or D.C.D. Sports coaches, not surprisingly, typically possess a good working knowledge of sports science, a good understanding of human movement skills and an excellent knowledge of the ways in which human performance can be improved, ranging from improving fitness, improving skill or increasing psychological skills such as confidence, which should make them ideal candidates for helping children to improve their movement skills. However, most sports coaches focus their limited time on elite performance and elite performers rather on those with little interest in sport and no likelihood of succeeding in it and who seek to avoid sport at every opportunity. This research will follow the usual pattern of research by applying the specialist skills, knowledge and experience of the researcher to the problem addressed. In addition, the author will attempt to review the current knowledge from other areas of scientific research and integrate that with his specialist knowledge of sports science, sports coaching and human movement skills and bring this to bear on the problem.

3.2: Selection of subjects

Children in the United Kingdom who are found to experience movement skills difficulties which are likely to affect their educational performance are assessed using the Movement A.B.C. Test (Henderson & Sugden, 1992). This test standardises the results so that 5% of all children are diagnosed with the condition. Assuming a U.K. population of sixty million, an average life expectancy of 60 years and 50 years having passed since D.C.D. was first identified, a very rough calculation would estimate that there should have been 2.5 million people diagnosed with D.C.D. in the U.K. since 1960. However, testing for D.C.D. has been patchy and those diagnosed have remained in mainstream schools, which makes access to the children and research into the condition difficult. In order to perform research on children who have already been diagnosed then it is essential that the school has taken seriously its responsibility to assess all children for D.C.D., who potentially possess movement difficulties. It is then necessary to arrange to remove the children identified as having D.C.D. from lessons or to persuade parents to allow them to remain after school. The results of any research could therefore be tainted by the school's failure to test those who possess the condition or the researcher's inability to secure the children's removal from lessons. The alternative, which has been adopted in this research, is to randomly select entire school year groups and carry out the research on all the children.

Every school taking children between 8 and 11 years of age within the London Borough of Croydon (See Appendix 11) was approached to secure their co-operation with the research. A list of these schools is shown at Appendix 12. Ten schools expressed an interest in participating in the research and presentations were arranged for the governors and management, setting out the aims and structure of the research. Eventually six schools agreed to participate, whilst four schools expressed the opinion that protracted research, taking six months to complete, would be an unreasonable burden to the school curriculum. One of the six schools that agreed to participate later withdrew, due to internal management problems. The schools which agreed to participate in the research came from across the borough and included an excellent balance in terms of the social background and achievement of their pupils, as can be seen from their most recent Ofsted inspection reports. (See Appendix 12) The schools agreed to send letters (Appendix 16) to every parent setting out the details of the proposed research and including a set of photographs of children participating in the same research at other schools (Figure 1) in order to assist parents' understanding of the proposed research. Following a great deal of work from the schools every parent consented and every child participated in the research, which provided a cohort of approximately eight hundred children for the research, which by the end had been reduced to approximately five hundred children. The main reasons for these withdrawals being absence, illness, holidays, disciplinary action and removal of the child from the school.

One solution is to combine the features of Physical Education with the principles of unsupervised play, to produce what will be referred to here as "Feral Play". It is supervised with a light hand, involves all the principles of competition that motivates children, is great fun and involves exercise of the type likely to improve strength and endurance explosively. Involving vigorous exercise as it does, it may even improve body composition and movement skills. Before the children arrive the adult should check the environment and the equipment to be used during the session so as not to affect the ambiance of the session. All children taking part are encouraged to take a drink and use the toilet before starting the session, so that breaks during the session are not required. Each session lasts for just 30 minutes, which is longer than most children can currently sustain high-intensity exercise. At the end of the session all children taking part are encouraged to take a drink and use the toilet so that all requests for breaks may be safely and confidently declined during the session.

In order to formalise the definition of "Feral Play" and to encourage teachers and sports leaders at schools to experiment with it, the following guidelines have been produced by the author of this research:

Feral play refers to the way that children used to amuse themselves in decades gone by. It relates to the uncontrolled, unrestrained way in which children used to play when let out of the house to meet up with friends and only return in time for their evening meal.

Feral play is physical, competitive activity. No breaks are taken for refreshment, drinks, toilet or even injury. It requires, and develops great strength, endurance, fitness, co-ordination, movement skills and self-confidence.

In its natural form, feral play does not involve adults, but the involvement of adults does not, in itself, prevent feral play from taking place, provided that the adult involvement does not become authoritarian, intrusive or break any of the other rules.

1. Supervised feral play should be limited to 30 minute sessions and start with a drink and use of the toilet, so that later requests for breaks may be safely declined.

2. The usual safety requirement for the environment, the equipment and the athletes (injury and dress) to be checked can be observed before the children arrive.

3. Simple safety rules, such as "no go areas" are rigidly enforced. This may involve gymnasium equipment, etc. These should be kept to a minimum and may develop over time.

4. Any violence, physical confrontation, breach of the rules or cheating requires a warning before a short exclusion, maybe two minutes, if repeated.

5. The adult should imitate a rugby union referee as closely as possible, by constantly giving out instructions and naming offenders and giving personal instructions in order to gain compliance.

6. All unnecessary limits and restraints are avoided.

7. All injuries not witnessed by staff are ignored for one minute. Without attention most children will be keen to resume the activity. A little blood or a bruise or a sting will be forgotten in the heat of the moment.

8. All activities are based on competition and competition is encouraged as a positive activity.

9. The adult must be enthusiastic, relaxed and possess a long and varied list of challenging activities.

10. All sessions must end with a drink and use of the toilet, as no breaks will have been permitted during the session.

These rules clearly caused the class teachers a degree of professional embarrassment. Duty Principals patrolling the schools questioned the need for the children to make noise, either from their exertions or due to them expressing their enjoyment of the session and accused teaching staff of lacking control of their classes. As a result of this it was agreed that the classes would be run by the researcher with the assistance of the class Learning Support Assistant. Several minor injuries were reported, none were treated, none were remembered sixty seconds after occurring and none were reported subsequently to the school. Whenever weather permitted the classes were taken outside to playing fields and playgrounds removed from the other classrooms, where the children were able to become competitive, make noise and run wild without disturbing other classes in more formal and academic classes. Staff, many of them specialist P.E. staff, observed that the children looked forward to the lessons, exerted themselves strenuously during the lessons and upon their return to class told stories of their experiences in the classes. Many of the children have asked when the classes will re-start. During informal conversations, members of staff have reported that the children's behaviour has shown a marked improvement following these classes. At least one of the schools which participated in the research has changed its policy in relation to the reporting for accidents, as a result of staff experience during the research.

Wherever possible, all testing and intervention work was undertaken outside the schools in playing fields and playgrounds away from other classrooms where the children could run wild and make noise. The only exception to this was during the Entropy testing, where the results could have been affected by the weather conditions. During times of severe weather it became impossible to take the children outside then classes were held in the school hall or the school gymnasium. The only equipment used in the intervention were standard school gymnasium benches for the straddle jumps and tennis balls for the gripping exercise.

Chapter 4: Study 1: Methods of Assessing D.C.D: A comparison between the Movement A.B.C Test and the Entropy Test

4.1: Introduction

The purpose of this study was to evaluate the use of approximate entropy as an assessment tool for identifying cases of D.C.D. by comparing it with the Movement A.B.C. Test (Henderson & Sugden, 1992), which is currently universally recognised in the U.K. as the best test for D.C.D., despite the criticisms of it set out above.

At present, all children in the United Kingdom who are suspected of experiencing movement difficulties are assessed in an educational or medical environment, using the Movement A.B.C. Test (Henderson & Sugden, 1992). The test is less than satisfactory for a number of reasons, primarily due to a lack of reliability and validity and a surfeit of subjectivity, particularly in the Checklist which forms the second part of the test. Two authorative studies support these views. The first study compared the results of nineteen tests of children's movement skills and came to the conclusion that "there is very little agreement within and across studies in the identification of clumsy children" (Keogh 1982, p. 247). The second study, a comparison of the two most popular tests, the Movement A.B.C. Test, favoured in the U.K. and the Bruininks Oseretsky Test, favoured in the U.S., found significant differences in the results and a correlation of only 0.80, that neither test was better than the other, but rather that the best results were achieved by undertaking both tests. (Crawford, Wilson & Dewey, 2001). Sugden, one of the authors of the Movement A.B.C. test has accepted many of the criticisms levelled against it and stated that "most primary school teachers can name those of his or her students with the condition after just a short time of working with them in class." (Sugden & Wright 1998, p.53). Parents and teachers have commented on the duration of the test, the cost of the testing kit, its portability, the facilities and equipment required to conduct the test and the need for staff training in order to undertake the test. An alternative test capable of satisfying the usual standards of validity, reliability and objectivity would be well received and perhaps secure the universal recognition that has so far, after almost twenty years, eluded the Movement A.B.C. Test.

Any new test will require the assessment of the children during the performance of a movement task, which is equally familiar to all the participants. This may be facilitated by selecting a task with which no child is likely to be familiar or by selecting a task with which all children are experienced and skilled. Human walking is a highly automated, rhythmic motor behaviour that is mostly controlled by subcortical locomotor brain regions. Yet human walking patterns, kinematics and kinetics, are unique. Indeed, recognising people by their gait has emerged as a practical biometric (Foster, Nixon & Prügel-Bennett, 2003; Nixon, Carter, Shutler & Grant, 2002). Each person's ideal gait is a combination of periodic movements determined by the body characteristics and the personal ability to control the gait. In the case of neuromuscular and musculoskeletal pathologies or injuries, these movements are not periodic and provide random variability. The walking pattern variability reflects the quality of the individual neuromuscular control and increases in cases of neuromuscular and musculoskeletal pathologies or injuries (Arehimedes, 2006).

4.2: The Movement A.B.C. Test

The Movement A.B.C. Test (Henderson & Sugden, 1992) is an established test and the instructions are set out in full in Appendix 4 and were carefully complied with throughout the research. The activities which make up the Movement A.B.C. test are described in detail in Appendix 5 and illustrated in Figure 1. The scoresheet published with the kit and used to calculate scores, is set out in Appendix 6. The results of the test are statistically adjusted to provide for 5% of the children being assessed to be found to have D.C.D. The checklist which does not contribute to the calculation of the Movement A.B.C. score, but which is designed to assist the assessor with an understanding of the causes of an individual child's movement difficulties was not undertaken as part of this research.

4.3: The Entropy Test

Accelerometer methods have proved an appropriate and reliable alternative approach to conventional gait analysis techniques (such as optoelectronic and force platform motion) for gathering gait data (Meyden, 1997). This involves the use of accelerometers attached to the body for the purpose of examining segmental and whole body accelerations during walking (Kavanagh & Menz, 2008; Meyden, 1997). Accelerometer sensors are low cost, small, light and easy to be adopted into portable measuring systems. Importantly, testing is not restricted to a laboratory environment, and the small size of accelerometers enables subjects to walk relatively unrestricted (Pober et al., 2005). Human body motion acceleration measurements have been analysed with the use of entropy, as a measure of randomness, during the last two decades. For example, Khandoker, Palaniswami & Begg, 2008 used entropy methods to identify gait variables that reflect gait degeneration due to ageing.

Shannon introduced the term entropy in order to quantify the information on a signal (Arehimedes, 2006). The concept of entropy was proposed as a general measure for both the randomness and harmony by Christakis (2006). The entropy is correlated, by definition, to the variability and the randomness while harmony is defined as the property of systems to match each other. Systems in harmony provide periodic, repeatable and identical behaviour and thus they are easy to be recognized and serve for definite, prescribed purposes, able to be matched to related systems. Christakis (2006) distinguished between harmony and randomness, proposing appropriate models for each concept. The entropy stands as a basic concept to measure the randomness of systems. Entropy reduction is considered as an indication but not a measure of harmony. Randomness is a different concept from harmony. Because of the relationship between entropy and harmony and the existence of relevant mathematical formulations, entropy was introduced as a measure to evaluate the quality of the human gait, such as to detect injuries and pathologies. In 1991, Pincus introduced the approximate entropy technique. Approximate entropy (ApEn) is a technique that can be used to quantify the irregularity or variability of short finite time series based on the statistics. Thus, ApEn is a measure of likelihood of predicting future behaviour of a time series based on past values of the signal. Arif et al. (2002; 2004; 2006) proposed accelerometers and ApEn for studying the effect of fatigue on walking stability and the walking stability of young and elderly subjects.

Whilst Kavanagh et al. (2005) used ApEn for studying the effect of ageing on the pattern and structure of head and trunk accelerations during walking.

Gait Evaluation Differential Entropy Measure (GEDEM) (Papadakis, Christakis, Tzagarakis, Chlouverakis, Kampanis, Stergiopoulos, & Katonis, 2009) is a new quantitative approach to evaluating the condition of a subject by monitoring the acceleration (Papadakis, Christakis, Tzagarakis, Chlouverakis, Kampanis, Stergiopoulos, & Katonis, 2009; Stylianos et al, 2008). The approach is capable of identifying medical conditions and is also not dependent on age, weight, height or BMI. A lightweight device attached to the subject records the gait acceleration. Through spectral analysis it is possible to estimate and quantify the level of uncertainty in the movement and summarize it in the GEDEM index.

Thus, walking is a dynamic action where the subject is constantly required to reassess his or her balance as the bodyweight shifts from one foot to another and it is necessary to maintain the centre of gravity directly above the base formed by the area between the two feet in order to retain that balance and to avoiding falling. This study employs approximate entropy to assess and compare walking stability among the subjects.

4.4: Methods

4.4.1: Participants

Participants were 46 primary school children [19 female; 27 male; (age = 9.5 ± 0.5 years; height = 137 ± 0.0 cm; weight = 35.4 ± 5.7kg; BMI = 18.7 ± 2.6]. The children participated in the research at school, in school uniform and school shoes, in the presence of their regular class learning support assistant, in place of lessons.

Prior to the commencement of the research, comprehensive oral presentations were made to the governors and senior staff at each of the schools, setting out the aims and methods of the research. Subsequently, detailed letters (appendix 16) and coloured illustrated leaflets (figure 1) setting out the aims and methods of the research were sent by the schools to the parents of each of the participants and their informed, written consent (appendix 17) secured.

4.4.2: Procedure

4.4.2.1: Teacher Assessment

Sugden, one of the authors of the Movement A.B.C. Test stated that the best test for D.C.D. was to ask the children's form teacher (Sugden & Wright, 1998). This method of assessing children has clear limitations in terms of subjectivity and because the teacher's knowledge is limited to the thirty children in his or her class. With each school class containing approximately thirty children and with the Movement A.B.C. test results being statistically adjusted so that 5% of those tested are diagnosed as having D.C.D., (Henderson & Sugden, 1992) each class should statistically be expected to have two children possessing the symptoms of D.C.D.

Accordingly, at the start of the research the class teachers and learning support assistants from each of the classes from which children participated in the research were asked to write down the names of the two children in their class who they believed to possess D.C.D. and place these names in a sealed envelope to be opened when the Movement A.B.C. Test results were known, without revealing the names to the researchers. Despite the fact that the teachers and learning support assistants were not allowed to consult prior to making their selections, there was complete agreement between them on the children named.

4.4.2.2: The Movement A.B.C. Test

Measurements were performed in the morning, during school hours. Subjects wore school uniform and shoes. The class was taken through each activity in turn until every pupil had completed the task and the class then moved on to the next activity. All results were recorded by a pupil selected from the class and all recording was very carefully supervised.

4.4.2.3: The Entropy Test

The measurement device was attached to an elastic belt. The operator of the measurement device placed the belt near the 5th lumbar vertebrae. (See Figure 2) The measurement device measured the approximate gait acceleration of the Centre of Gravity (COG) of the subject's body. It is not possible to measure the exact acceleration of the COG, because the subject's COG may be inside the body. The variability of the acceleration of the centre of gravity is analysed along each of the three axis, x, y and z, where the x axis relates to movements in the anterior/ posterior plane, the y axis relates to movements in the medial/ lateral plane, and the z axis relates to movements in the vertical plane and using the principles of approximate entropy in order to assess their movements and to subsequently rank the subjects.

The low weight of the measurement device minimized the influence it exerted on the subjects' walking. Every precaution was taken in order to minimise distractions to the subjects during the measurements. All subjects were instructed to walk along a 40m straight hospital level walkway at a self-selected walking speed.

Gait acceleration signals were obtained for each axis at a sampling rate of 128[Hz]. The measurement duration was 30[sec] in order to obtain a time series that could be truncated and still produce a power spectrum with a frequency component resolution (df) lower than 0.1[Hz]. The signal was truncated before processing. The first and last two (2) gait cycles were removed, because it was deemed that acceleration and deceleration would contribute to variability.

The testing was performed at the same time and in the same place as the Movement A.B.C. Test and the set of strength tests so as to avoid any fluctuations in strength or skills and in order to permit a fair comparison of the results.

4.4.3: Measurement devices

4.4:3.1: The Movement A.B.C. Test

The approved Movement A.B.C. Test kit (Henderson & Sugden, 1992), produced by Pearson Assessments on behalf of the authors of the test, was used for all testing.

4.4.3.2: The Entropy Test

The measurement device consisted of a tri-axial digital output linear accelerometer LIS3LV02DQ, a microcontroller, a voltage regulator (MC33269D3,3), a 4MB flash memory, a transceiver and a battery. The measurement device was based on an 8-bit micro-controller; ATTINY2313. The device dimensions were 125x65x25 mm and it weighed 150 g (including a 9V battery). Low weight was important for minimizing interference in the measurement. The maximum sampling rate of the measurement device was 2000[Hz], and the MEMS accelerometers were able to measure acceleration up to ± 2[g]. The sampling frequency in this study was selected at 128[Hz], after examining the frequency content of normal walking at sampling rate of 256[Hz], 512[Hz] and 1024[Hz]. The previous studies showed that sampling frequencies higher than 1024[Hz] were not used because frequency response of MEMS accelerometers is very poor beyond 1000[Hz], and therefore the gait accelerations measurements would have been questionable. Most gait analysis studies usually sample at 100-500[Hz]. Earlier studies suggested higher sampling rates and then performed low pass filtering of the signal (usually a first or second class Butterworth filter [1][2], while more recent work suggests lower sampling rates without any filtering [3][4][5].

The data were transferred to a PC via an RS232 port. The data were stored on a PC in ASCCI tagged format for easy retrieval. In this study, although all accelerations were recorded, only vertical (z)-axis acceleration was used, because I considered that the magnitude of the ground reaction force vertical component is greater than the medio-lateral and anterior-posterior components, it was most likely to indicate change (Hamill & Knutzen, 2009).

An analysis of the combined accelerations (x, y and z) was not conducted due to limitations of the measurement protocol. The measurement protocol did not specify a standardized gait velocity (on the x-axis – anterior-posterior) during the measurement. As a result, the gait cycle length on the x-axis was different because it depended on gait velocity. Also the acceleration on the y-axis (transverse or medio-lateral) was not considered suitable for analysis. Slight gait deviations from a straight line, could induce perturbations in the medio-lateral acceleration. Despite the fact that these deviations are not necessarily attributed to pathology, they contributed to gait variability. The vertical (z) displacement was selected because it minimized the issues of the other directions. More specifically, the vertical travel distance in a gait cycle was considered constant regardless of the gait velocity. Additionally, the gait variability in the z-axis was not considered to be affected from gait deviations from a straight line. Finally, the z-axis was selected because of its predominant frequency which is double the respective frequency of y-axis. In each gait cycle (left and right step) the Centre of Gravity moves vertically twice and laterally only once. As a result the frequencies are spread along a wider range (compared to the y-axis). In the future, the inventor of the device used in this research intends to develop a measurement protocol involving a treadmill that will allow analysis of combined accelerations.

4.4.4: Calculation of Results

4.4.4.1: The Movement A.B.C. Test

All scores were calculated using the Record Form (Appendix 6) supplied with the official Movement A.B.C. test kit.

4.4.4.2: The Entropy Test

The differential entropy of the gait acceleration signal was calculated using the method that was described by Papadakis &Christakis (2008). Differential entropy is an extension to Shannon's Entropy to continuous variables. Differential entropy is defined [7], as:

$$h(x) = -\int f(x) \cdot \log_e(f(x))\, dx \tag{1}$$

where f(x) is the probability density function of continuous variable x (x belongs [a,b]).

In most cases it is very difficult/impossible to analytically determine f(x), however it is possible to calculate approximately the entropy of a continuous variable using a discrete (numerical) approximation (Papoulis, 1984).

By the mean-value theorem there exists a value x_i in each bin such that

$$\int_{i\delta}^{(i+1)\delta} f(x)\, dx = f(x_i)\delta \tag{2}$$

Then the integral of f(x) can be approximated (in the Riemannian sense) by.

$$\int_{-\infty}^{\infty} f(x)\,dx = \lim_{\delta\to 0}\sum_{i\to-\infty}^{\infty} f(x_i)\delta \tag{3}$$

By denoting:

$$H_\delta = -\sum_{i=-\infty}^{\infty} \delta\cdot f(x_i)\cdot \log_e\left(\delta\cdot f(x_i)\right) \tag{4}$$

and expanding the logarithm, eq. (4) becomes:

$$H_\delta = -\sum_{i=-\infty}^{\infty} \delta\cdot f(x_i)\log_e(\delta) - \sum_{i=-\infty}^{\infty} \delta\cdot f(x_i)\cdot \log_e\left(f(x_i)\right) \tag{5}$$

Given that f(x) satisfies the conditions of a probability density function, the following is true as $\delta\to 0$:

$$\int_{-\infty}^{\infty} f(x)dx = 1 = \lim_{n\to\infty}\sum_{i=-\infty}^{\infty} \delta\cdot f(x_i) \tag{6}$$

And therefore the second term of eq.5:

$$-\sum_{i=-\infty}^{\infty} \delta\cdot f(x_i)\log_e\left(f(x_i)\right) \to -\int f(x)\cdot \log_e(f(x))\,dx \tag{7}$$

However, as bin length δ tends to zero $\delta\to 0$, $\log\delta\to -\infty$, and eq.1 becomes:

$$h(x) = -\int f(x)\cdot \log_e(f(x))\,dx = \lim_{\delta\to 0}[H_\delta + \log_e(\delta)] \tag{8}$$

Therefore, in order to obtain the entropy of the continuous variable, the following formula (eq.9) is used [7].

$$h(x) \approx -\sum_{i=-\infty}^{\infty} \delta\cdot f(x_i)\cdot \log_e\left(f(x_i)\right) + \log_e(\delta) = H_\delta + \log_e(\delta) \tag{9}$$

In order to obtain the differential entropy of a continuous variable h(x), the Shannon's entropy of the quantized variable H_δ needs to be corrected by the quantisation factor δ. Therefore, the above approximation of the continuous variable differential entropy is invariant to the discretisation factor δ. This is a significant benefit compared to the ApEn or Multiscale Entropy that are dependent on proximity parameters (i.e. parameter r).

In order to detect frequency irregularities in a time series, the power spectrum of a signal was obtained. The power spectrum PS(φi) of the acceleration signal is obtained, where φi is the i-th frequency component (the 0 component is the DC component). Generally, each frequency component is φi=i*Δφ [Hz], where Δφ is the frequency interval of the power spectrum in [Hz]. The power spectrum is normally obtained in the form of a vector, in a similar manner that the continuous variable x is quantized into variable xi. The power spectrum is divided by the integral of the power spectrum.

$$\mathrm{PS}'(\varphi_i) = \frac{\mathrm{PS}(\varphi_i)}{\int_0^{\frac{f_s}{2}} \mathrm{PS}(\varphi)\mathrm{d}\varphi} \tag{10}$$

Where f_s is the sampling frequency.

The integral of the normalised power spectrum PS'(φi) over the frequencies (0, $f_s/2$) is equal to one. The differential entropy is then applied to the normalised power spectrum PS'(φi) – (eq.11).

$$h(x) \approx -\sum_{i=0}^{n} \Delta\varphi \cdot PS'(\varphi_i) \cdot \log_e\left(PS'(\varphi_i)\right) + \log_e(\Delta\varphi) \tag{11}$$

If the signal is periodic (low variability in the frequency domain), then there will be a predominant frequency component and therefore lower differential entropy values will be obtained. On the other hand, if a signal is random (e.g. white noise), then more frequency components with relatively high power are selected and therefore higher differential entropy values. The range of values for the differential entropy of the normalized power spectrum is [loge(Δφ), Δφ loge(n) + loge (Δφ)]. Therefore, a low spectral differential entropy value is associated with periodic gait acceleration time series, while high spectral differential entropy values are associated with irregular gait acceleration time series.

Depending on the logarithmic base, differential entropy is measured Bits for log base 2, Nats for log base e and bans in Log_{10}. The selection of the base will not change the results qualitatively. The base that was selected in this study was **e**, and therefore the units of the differential entropy are in [**Nats**].

4.4.5: Statistical Analysis of results

4.4.5.1: The Movement A.B.C. Test

All scores were calculated using the formulae on the official Record Form (Appendix 6) supplied with the official Movement A.B.C. test kit.

4.4.5.2: The Entropy Test

The entropy measurements were averaged for each subject. A T-test is used to compare the spectral differential entropy values between the two groups (null hypothesis is that the mean values are equal pre and post the six week intervention. A t test was also used to compare pre and post Movement A.B.C. data). SPPS 15.0 and the R study for statistical computing v.2.8.0 was used for statistical analysis. A significance level of a=0.05 was used.

4.5: The Strength Training Intervention

All the participants followed a six week strength training intervention based on the programme set down by UK Athletics in the Elevating Athletics scheme set out in Appendix 9. The programme is laid down in Appendix 10 and involved two thirty minute sessions each week. It consists of a range of sprinting, hopping and bounding activities designed to improve strength and fitness, particularly in the legs and back. The feedback received from the children, particularly in the first week or two of the intervention, indicated that they found the intervention strenuous and challenging, but as it was fun, they were enjoyed it and were happy to continue with it.

4.6: Results

4.6.1: The Movement A.B.C. Test

The results of the participants in each of the tests in the Movement A.B.C. Test are summarised in the table below:

Test Items	$\bar{x} \pm$ SD Pre-intervention	$\bar{x} \pm$ SD Post-intervention	t	df	p
Peg test (right hand)	18.14 ± 5.41	16.41 ± 4.55	8.75	471	0.000
Peg test (left hand)	19.91 ± 6.09	18.20 ± 5.60	8.32	471	0.000
Nut test	19.30 ± 9.73	18.69 ± 8.95	1.57	471	.11
Catch test	6.51 ± 2.89	7.26 ± 2.75	2.54	471	0.000
Bag test	4.88 ± 2.27	5.78 ±2.29	-8.72	471	0.000
Balance test (right leg)	5.53 ±6.02	6.99 ±6.67	-6.07	471	0.000
Balance test (left leg)	5.03 ±5.83	5.56 ±6.13	-2.31	471	.021
Hopping (right leg)	4.48 ±1.12	4.42 ±1.15	.94	471	.34
Hopping (left leg)	4.36 ±1.19	4.35 ±1.18	.099	471	.92
Ball balancing test	0.36 ±1.08	.25 ±.73	2.32	471	.019
Dexterity	9.68 ±4.45	8.61 ±4.39	6.41	471	.000
Ball skills	2.01 ±2.34	1.30 ±1.90	7.91	471	.000
Balance	7.89 ±5.02	7.29 ±5.12	2.73	467	.006
Total Movement A.B.C. Score	19.61 ±8.32	17.22 ±8.24	8.51	467	.000

Table 1: Descriptive results of the tests in the Movement A.B.C. test pre- and post-intervention.

4.6.2: The Entropy Test

The resultant entropy values of all the participants pre- and post- the six week strength training intervention programme are shown in figures A, B and C below, for the anterior/posterior, medial/lateral and vertical planes.

Amplitude DE X

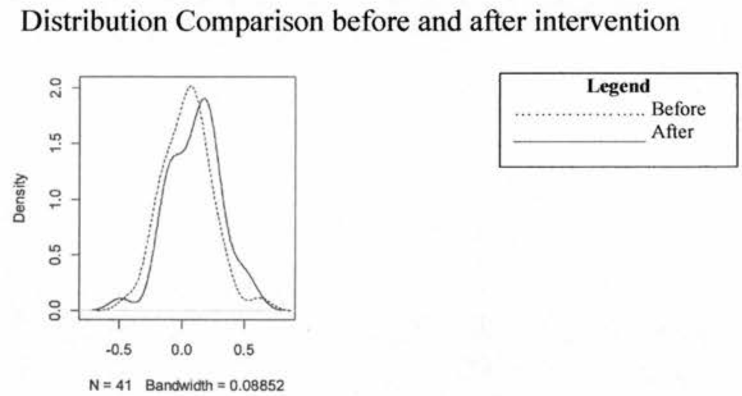

Figure A: Distribution Differential Entropy X – Axis (anterior - posterior plane). Comparison of values before and after intervention

The DDE X is not statistically significant ($p<0.5$). ($t = -1.6683$, $df = 40$, p-value = 0.1031). The DDE-X represents the variability in the distribution of the longitudinal (Anterior and posterior) forces. This index was expected to remain constant, because the gait velocity was self selected.

Amplitude DE Y

Distribution Comparison before and after intervention

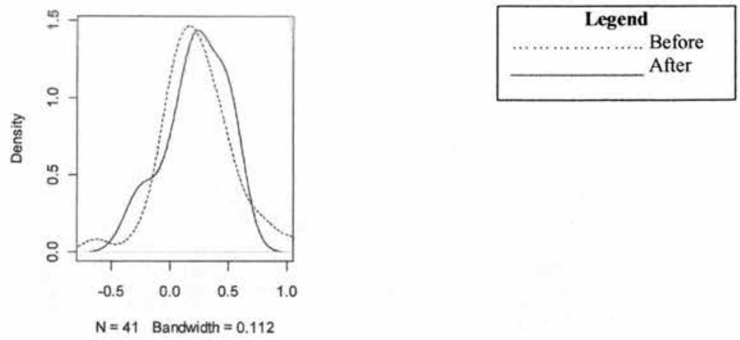

Figure B: Distribution Differential Entropy Y– Axis (medial - lateral plane). Comparison of values before and after intervention.

The DDE Y is not statistically significant ($p<0.5$). $t = 0.2063$, $df = 40$, p-value = 0.8376. The DDE-Y represents the variability in the distribution of the medio-lateral (Left and right) forces. This index was expected to remain constant, because the gait velocity was self selected.

Amplitude DE Z

Distribution Comparison before and after intervention

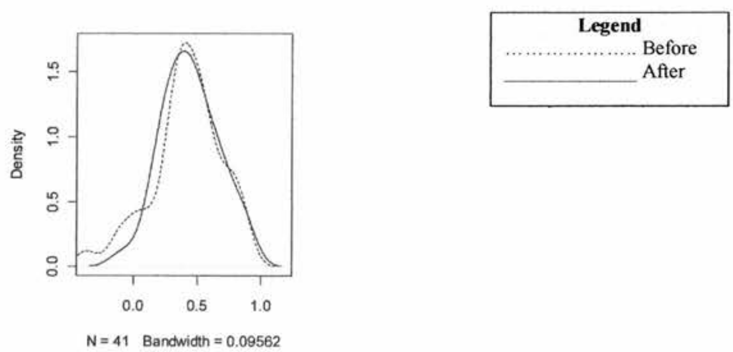

Figure C: Distribution Differential Entropy Z – Axis (vertical plane). Comparison of values before and after intervention.

The DDE Z is not statistically significant ($p<0.5$). $t = -0.789$, $df = 40$, p-value = 0.4348. The DDE-Z represents the variability in the distribution of the vertical (up and down) forces. This index was expected to remain constant.

The integrated values pre and post intervention were calculated, and although there was a positive percentage increase post for the Y and Z components it was non-significant. The integrated values are shown in table 2 below.

Table 2: Integrated results for the amplitude of X, Y and Z components pre- and post- intervention.

	Pre intervention	Post intervention	% change pre to post
Amplitude DE X	60.5	60.4	+ 0.2
Amplitude DE Y	73.0	80.6	+ 10.4
Amplitude DE Z	66.0	73.8	+ 11.8

4.7: Discussion and Conclusions

4.7.1: The Movement ABC Test

The Movement A.B.C. Test is almost twenty years old. It is universally accepted in the United Kingdom as the official and best test for D.C.D. (Boon, 2002; Kirby & Drew, 2003; Macintyre, 2001). Despite the extensive list of weaknesses that were revealed in the literature review and confirmed by the study. Its greatest strength is that it allows children with movement difficulties to be assessed in a range of activities that allow a trained and experienced assessor to identify the specific problems that underlie the difficulties that the child is experiencing and which have been identified by parents and/ or teachers, thereby prompting the assessment. The test also allows an element of objectivity to be introduced into the assessment, which is essential if support and assistance is to be provided to the child from a publicly funded service, such as Education or Health.

This study has failed to provide the scientific evidence of validity and reliability necessary to replace the Movement A.B.C. test at this time, but it has very clearly established that there is a need to continue the search for a replacement and that Entropy is sufficiently sensitive and convenient to use to be a useful place to continue researching. The study has highlighted the problems associated with comparing a new assessment method with an established, but flawed, assessment method, such as the Movement A.B.C. test. A case can be made for undertaking future research in class-sized groups in order that any new assessment methods can be compared with the assessment method which has been accepted as providing the most accurate results presently available, the judgement of the teacher. A test which is capable of objectively, conveniently, speedily and cheaply identifying the same children as having D.C.D. as the class teacher will be invaluable. Such a test would permit universal testing of all children for D.C.D. to prevent children with the condition being missed due to careless or untrained teachers missing the signs and symptoms and arranging an assessment. It would also assist researchers attempting to identify the causes of the disorder and a precise list of symptoms of the disorder, which would combine to improve knowledge of the disorder and assist in the treatment of those with the disorder.

4.7.2: The Entropy Test

The decision to apply the principles of Approximate Entropy to the problem of testing children with movement difficulties for the incidence of D.C.D. was innovative. Whilst there was no significant correlation between the results of the Movement A.B.C. test and the Entropy Test, this may, in part, be due to the deficiencies found in the Movement A.B.C. test in identifying those children with D.C.D. The accelerometer showed itself to be capable of identifying minor fluctuations in movement and this fact, combined with the theoretical basis of the research indicate that this research continues to have the potential as an assessment tool for D.C.D. The size of this study was restricted by technical problems with the accelerometer that required its return to the manufacturer for repair. It may be that a larger study may provide results that are statistically significant and that, if not, improvements in the design and production of the accelerometer will produce such results. Use of the accelerometer removed all the practical difficulties in testing children for D.C.D. and indicated that if valid and reliable test using these principles could be found, then universal testing of all primary school children would be feasible and viable.

4.7.3: The Way Forward

The results produced by the Entropy Test show some promise for the future. The theory behind the system is sound and the technology is sensitive to minor movements by the subject and is constantly improving. Although the changes in Entropy in this study are not statistically significant, there are changes visible in the graphs (figures A, B and C) that are worthy of further investigation and which may, with increased numbers of subjects prove important in future research. Unfortunately, it was not possible to continue with further research using the entropy data collection equipment due to technical malfunction. The decision was made to progress with further study using the Movement A.B.C. Test.

Chapter 5: Study 2: Strength as a factor in the incidence of D.C.D

5.1: Introduction

Patterns of physical activity in young children have changed fundamentally in the last century. (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland.....& Li, 2001) Self-determined and self-regulated free play (Schraw, Crippen & Hartley, 2006) has almost completely disappeared due to a range of social, cultural and lifestyle changes that have taken place during this period (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland.....& Li, 2001), ranging from the reduction in the need for manual labour resulting from the Industrial Revolution, increased fear of child abuse, mass car ownership and the ready availability of electronic entertainment equipment. Only a belief, largely unsupported by scientific evidence, that the health and fitness of our young people will be affected by a lack of exercise (Rowland, 2007) and the need for healthy recruits to the Armed Forces (Baden-Powell, 1908), has stemmed the decline. Parents, keen to ensure the health and fitness of their children, are arranging for them to participate in competitive sports, (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001), such as football, rugby, basketball and martial arts, where they will be protected, encouraged and coached by trained and approved professional staff. Simultaneously, the levels of fitness and the quality of the movement skills of our young people have troubled commentators (*British Medical Journal*, 1962; Nordau 1892; Baden-Powell, 1908).

It is widely recognised that free play by children allows for the development of motor skills (Piaget, 1962 in Rowland, 2007; Washington, Bernhardt, Gomez, Johnson, Martin, Rowland ...& Li, 2001). Children need to learn a range of key movement skills in their early years, including throwing, catching, kicking and hitting a ball. These skills need to be learned at definite stages of each child's development and do not develop sooner simply as a result of introducing them to children at an earlier age. (Branta et al., 1984 in Washington, Bernhardt, Gomez, Johnson, Martin, Rowland ...& Li, 2001) They have traditionally been learned whilst participating in free play with the lessons reinforced during school physical education classes. Unfortunately, the reduction in time spent on free play has coincided with school physical education programmes diminishing in duration and content (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001) and as no competitive sport includes all of these skills, the skills are deteriorating. It is also necessary to consider the motivational factors acting on the children in play.

> For children and preadolescents, factors such as fun, success, variety, freedom, family participation, peer support, and enthusiastic leadership encourage and maintain participation, whereas others such as failure, embarrassment, competition, boredom, regimentation, and injuries discourage subsequent participation.

(Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001, p. 1460).

The informal nature of free play arouses many of the positive factors of variety, freedom and fun and permits a focus on success without the need to acknowledge failure, whilst the more formal competitive sport must include a certain amount of regimentation and competition that can lead to acknowledgement of failure and embarrassment and, with poor coaching, can lead to boredom and injury.

There are few similarities between free play and competitive sport. Children can engage in free play at any time including that time before their parents get up and when they are at work. Historically, children went out after breakfast and were told to return for their evening meal (BBC, 2009). In order to participate in organised, competitive sport, facilities have to be hired and professional coaches paid, so sessions are likely to be limited to just one or two hours. In free play children keep going until their exhaustion overtakes their enthusiasm, whilst in competitive sport professional coaches encourage and even enforce regular breaks. Free play involves a wide variety of activities partly due to its duration and anecdotal evidence suggests that it often included wrestling, lifting, throwing and climbing. These are not popular competitive sports, and participation in them is likely to have diminished and if this is the case then the strength of the children is likely to diminish also. A number of differences between free play and competitive sport are set out by the

Committee on Sports Medicine and Fitness and the Committee on School Health in their report entitled, "Organised Sports for Children and Preadolescents." which states:

> (Free play) in the early 20th century was a more regular part of life for the average child. Sports and games provided an additional outlet for physical activity and were characterized by play that was generally spontaneous, unstructured, and without adult involvement. Participation in such sports and games allowed for development of motor skills, social interaction, creativity, and enjoyment for participants.
>
> (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001, p.1439).

> Organization of sports has potential benefits of coaching, supervision, safety rules, and proper equipment but can also create demands and expectations that exceed the readiness and capabilities of young participants.
>
> (Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001, p.1440).

Unfortunately, the days when children had the time, opportunity, or inclination to play in neighborhoods or local parks have passed. "Today, there are more demands on a young person's time, more options for free time, diminished requirements for regular physical activity, and fewer opportunities for free play. School-based physical education programs have also been reduced throughout the years and can no longer be relied on to provide adequate levels of healthy activity!

(Washington, Bernhardt, Gomez, Johnson, Martin, Rowland .....& Li, 2001, p.1440).

Replacing free play with competitive sport is likely to introduce a number of other changes relating to the nature of the particular sport selected. The **frequency** of each session is likely to be restricted if adult coaches have to be paid at an hourly rate. The **intensity** of each session is likely to be restricted by cautious adult coaches. The **time** that each session lasts is likely to last is likely to be restricted if adult coaches have to be paid at an hourly rate. The **type** of training is likely to be decided by the parents who arranges for the child to attend or by the adult coach supervising the session in the case of general sessions. Frequency, intensity, time and type combine to form the F.I.T.T. principle used to assess the effectiveness of fitness training. (Walker, 2004)

5.2: Fitness.

Fitness is defined as "one's level of adaptation to the stressors of one's lifestyle" (Dick, 2003, p.212). The components of fitness include:

- Strength
- Strength endurance
- Aerobic endurance

- Speed
- Mobility

(Dick, 2003, p.214)

The components are very closely related and this relationship is illustrated in Figure 20. One of the key components of fitness is strength. Appropriate muscular strength in the muscles surrounding a joint being stretched is essential to avoid injury as stretching weak muscles is very likely to damage them and damage to the joint may result if surrounding muscles lack the strength to stabilise it during stretching. (Dick, 2003) Strength will positively influence speed (Dick, 2003) as muscles cannot move quickly if they are weak or restrained by heavy weight or resistance. Strength, like all of the components of fitness is affected by genetics, training and the athlete's lifestyle.

5.3: Strength

> Strength is defined as the ability to generate maximum maximorum external force.
>
> (Zatsiorsky, 2006, p.21)

With a definition discussing maximum external force and images of weightlifters breaking world records for the clean and jerk by holding 263 kg/ 580 lbs overhead and powerlifters breaking the world record for the squat with 457.5 kg/ 1007 lbs, it can be little surprise that strength is commonly associated with men with freakish muscles lifting outrageous weights. However, strength is clearly a measurable variable and whilst the champions are breaking their records some people lack the strength necessary to remain healthy and to perform the tasks of daily life. The B.A.S.E.S. Position Statement on Guidelines for Resistance Exercise in Young People describes strength as "essential for healthy living and the development of the healthy child." (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004, p.385). It has long been recognised that one of the most frequent causes of injury is muscle imbalance, (Chandler, Kibler, Stracener, Ziegler & Pace, 1992; Croisier, Forthomme, Namurois, Vanderthommen & Crielaard, 2002; Heiser, Weber, Sullivan, Clare & Jacobs, 1984) usually caused by a lack of strength in a muscle. This can occur at any age with some children emerging from the womb with muscle imbalances caused by awkward body positions whilst in the womb and with some geriatrics degenerating and losing muscle strength unequally around the body. Treatment for all such injuries must include the strengthening of the muscle to eliminate the weakness that caused the injury or it will be likely to recur. This treatment will follow the same principles as all strength training whether designed to build weightlifting champions or to assist recovery following injury.

Children with D.C.D. have been shown to have slack muscles and to lack muscle tone. (Oliveira, Shim, Loss, Petersen, & Clark, 2006) They have been described as lacking in strength in their fingers, hands and wrists, (Oliveira, Shim, Loss, Petersen, & Clark, 2006) which may relate to the difficulties that have been identified in completing a number of fine motor skills such as writing and drawing. A comparison of the symptoms of D.C.D., set out in Section 2.4 on page 34, and the physiological adaptations to resistance training, shown in Table 12, reveals a strong negative correlation and indicates a link between strength and the incidence of D.C.D. Raynor (1989; 2001) supports this and reveals a link with muscle activation and co-activation.

The present research will assess the strength of 472 primary school children and compare it with the results of tests of fine and gross motor skills contained in the Movement A.B.C. test used to identify cases of D.C.D., to see whether strength can be shown to be a factor in the incidence of D.C.D.

5.4: Methods

5.4.1: Participants

Participants were 472 primary school children [243 males and 229 females; mean age 9.2 ± 0.9 years, height 1.40 ± 8.9 m, body mass 36 0 ± 9.2 kg]. The children participated in the research at school, in school uniform and school shoes, in the presence of their regular class learning support assistant, in place of lessons. All the children in years 4, 5 and 6 at the six schools (see Appendix 12) within the London Borough of Croydon (see Appendix 11) which responded positively to a letter sent to all the primary schools in the borough, seeking their support for the research, participated.

Prior to the commencement of the research, comprehensive oral presentations were made to the governors and senior staff at each of the schools, setting out the aims and methods of the research. Subsequently, detailed letters (appendix 16) and coloured illustrated leaflets (figure 1) setting out the aims and methods of the research were sent by the schools to the parents of each of the participants and their informed, written consent (appendix 17) secured.

5.4.2: The Tests

5.4.2.1. The Strength Tests

Tests were selected to assess the children's strength which could be undertaken by children with a wide range of strength values and a range of movement skills. Tests were divided between static and dynamic strength and centred on the large muscles of the leg and back where children are reasonably well developed through running and jumping and the area around the fingers, hands and wrists where children with D.C.D. are known to experience muscle laxity and weakness (Oliveira, Shim, Loss, Petersen, & Clark, 2006). The use of dynamometers to test static strength is discussed in Appendix 8.

The tests selected were:

- Sargent jump (Figures 3 and 4)
- Triple standing long jump (Figures 5 and 6)
- Grip dynamometer (Figures 7 and 8)
- Leg and back dynamometer (Figures 9 and 10)

The figures listed next to each exercise illustrate and describe the techniques of each exercise and set out average performance results for school age children.

5.4.2.2: The Movement A.B.C. Test

All participants were assessed for D.C.D. using the Movement A.B.C. Test (Henderson & Sugden, 1992). The Movement A.B.C. Test is universally recognised as the test for D.C.D. in the United Kingdom, where this research was conducted. All assessments were performed using the officially accredited kit from Pearson Assessments. The introduction from the test is at Appendix 4. The individual tests that make up the Movement A.B.C. test are at Appendix 5. The record Form for the Movement A.B.C. test is at Appendix 6.

5.4.3: Experimental design

Arrangements were made for the testing to be performed out of doors, weather permitting, and in a school hall or gymnasium if it was not. This allowed a positive, encouraging, competitive atmosphere to develop. The tests were undertaken in order, with each child permitted three attempts at each exercise, with all results being recorded and the best result being used.

5.4.4: Measurements

- Sargent jump (Figures 3 and 4)
- Triple standing long jump (Figures 5 and 6)
- Grip dynamometer (Figures 7 and 8)
- Leg and back dynamometer (Figures 9 and 10)

The figures set down next to the exercises above describe and illustrate the technique for that exercise and set down mean performance results for children of school age.

5.4.5: Apparatus

Sargent Jump Test

The Sargent jump test was measured using the same digital jump meter on all occasions (TKL 5106 jump meter; Takey, Tokyo, Japan). The reported precision of the device was 1cm. When performing the test, the subject stood on the platform with his or her feet apart at a comfortable distance of hip width for balance. The subject was instructed to flex at the knees and then to extend the knees vigorously and to reach as high as possible. Each subject performed the test three times allowing a one minute rest period between measures.

Triple standing long jump Test

The triple standing long jump was measured using a standard metric tape measure. Each subject was instructed to stand behind a line set down on the ground in front of them. The subject was then instructed to jump two-footed as far as he or she could three times. Each subject performed the test three times allowing a one minute rest period between measures.

Measurement of grip strength.

Grip strength was measured using the same digital dynamometer on all occasions (TKL 5401 Grip-D; Takey, Tokyo, Japan). The reported precision of the device was 0.1 kgf. When performing the dynamometry, subjects maintained the standard bipedal position during the entire test with the arm in complete extension moving from overhead to the side of the leg, and did not touch any part of the body with the dynamometer except the hand being measured. Each subject performed the test three times with his or her preferred hand allowing a one minute rest period between measures.

Measurement of leg and back strength.

Leg and back strength was measured using the same digital dynamometer on all occasions (TKL 4502 Leg-D; Takey, Tokyo, Japan). The reported precision of the device was 0.5 kgf. When performing the dynamometry, the subject stood on the platform with his or her feet apart at a comfortable distance of hip width for balance and with his or her hands grasped at each end of the bar. The subject was instructed to flex at the knees and to keep the back straight and then to extend the knees as smoothly and as forcefully as possible. Each subject performed the test three times allowing a one minute rest period between measures.

5.4.6: Statistical analysis

Applying SPSS version 10.0 for statistical analyses, I considered differences of two-tailed $p < 0.01$ as statistically significant. All data were shown as means with standard deviations (means ± SD). Pearson's correlation coefficient was used to analyse the relationship between the Movement A.B.C. test scores, including the three constituent group scores of dexterity, ball skills and balance and the results of the four strength tests, the Sargent jump, the triple standing long jump, the grip dynamometer and the leg and back dynamometer.

5.5: Results

Table 5A: Descriptive statistics of Movement A.B.C. and Strength Tests

	$\bar{x}$	±SD
Dexterity Score	9.2	± 4.5
Ball skills Score	.7	± 1.2
Balance Score	7.2	± 3.6
Movement A.B.C. Test Score	17.2	± 6.7
Sargent jump (cm)	33.5	± 7.9
Triple standing long jump (cm)	4.23	± 0.7
Grip dynamometer (kgf)	15.8	± 4.5
Leg and back dynamometer (kgf)	46.9	± 13.4

The results of each of the strength tests are within the normal range set down for children of this age (Figure 4 for the Sargent jump; Figure 6 for the triple standing long jump; Figure 8 for the Grip dynamometer; Figure 10 for the leg and back dynamometer.). The result of the leg and back dynamometer are a little high but this may reflect the prevailing competitive atmosphere or the racial or social mix of the subjects.

A comparison of the results of the four strength tests and the results of the Movement A.B.C. Test show a significant correlation of between .19 and .40. When this is analysed in more detail by comparing the scores of the four strength tests with each of the component sections of the Movement A.B.C. Test, (dexterity, ball skills and balance), significant correlations of between .11 and .43 are shown.

Table 5B: Pearson Correlation Coefficient of Strength Test Results with Movement A.B.C. Scores.

	Dexterity	Ball skills	Balance	Movement A.B.C. Test Score
Sargent jump	-.14**	-.28**	-.21**	-.28**
Triple standing long jump	-.23**	-.43**	-.24**	-.40**
Grip dynamometer	-.20**	-.32**	-.17**	-.30**
Leg and back dynamometer	-.11*	-.15**	-.14**	-.19**

* p<.05
** p<.01

The strength test with the highest correlation to the Movement A.B.C. test and its component sections is the triple standing long jump, followed by the grip dynamometer, Sargent Jump and the leg and back dynamometer.

5.6: Discussion

The Movement A.B.C. is a battery of eight tests, some performed with each hand, some with either hand and some with both hands. (Henderson & Sugden, 1992) The battery is designed to identify a range of movement difficulties in children of primary school age and to assist experienced practitioners to identify the specific causes of the disorder in each child. The authors have made available a prepared kit to use when performing the test as well as extensive instructions as to the way in which the tests should be performed. However the test still requires a number of subjective judgements and decisions to be made and the scores are liable to be affected by a number of variables according to the location of the test and the ancillary equipment used, such that the results are not suitable for direct comparison. This is recognised by the fact that the authors did not stipulate a fixed score by which children would be diagnosed with the condition but set down that when groups of children are assessed at the same time and under similar conditions, the results should then be statistically adjusted so as to provide that 5% of the children are diagnosed as having D.C.D. Children with the most severe movement difficulties score highest in the test. (see Appendix 4)

D.C.D. is a condition which is usually identified in children of primary school age and indeed, the Movement A.B.C. test is specifically designed to be used with children of that age (Henderson & Sugden, 1992). The symptoms of the condition often persist as the person ages, but a number of adaptations and coping strategies minimise the effect of the symptoms (Kirby & Drew, 2003). Despite a number of authors identifying a lack of strength in the hands, wrists and fingers as being a symptom of the condition (Oliveira, Shim, Loss, Petersen, & Clark, 2006) very little research has been undertaken to measure the strength of either normal children or of those with D.C.D., so as to be able to confirm this observation. This is probably because measuring strength is not an area in which medical or educational researchers specialise. It may also be due to the fact that undertaking any form of strength exercise was seen as potentially injurious to the health of young people. The four strength tests selected are all popular activities with children and average results for those of school age, between five and eighteen years, have been published.

When the results of the four strength tests employed in this study are compared with the average results for children of the same age they are found to be slightly above average, but within the normal range. In the grip dynamometer the average for a boy aged 9.2 years is 19kgf and for a girl it is 16kgf (see figure 8) compared with the mean of 16.6kgf for boys and 14.9kgf for girls generated by children in this study. In the leg and back dynamometer the average for a boy aged 9.2 years is 22kgf and for a girl it is 20kgf (see figure 10) compared with the mean of 49.2kgf generated by boys and 44.4kgf by girls in this study. In the Sargent jump the average for a boy aged 9.2 years is 26cm and for a girl it is 25cm (see figure 4) compared with the mean of 35.4cm generated by boys and 31cm by girls in this study. In the triple standing long jump the average for a boy aged 9.2 years is 390cm and for a girl it is 390cm (see figure 6) compared with the mean of 428cm generated by boys and 414cm by girls in this study. The reason for these results being slightly higher that normal may be the multi-racial background of the participants and the fact that many have come from countries where they were encouraged to participate in sport and other physical activities from a young age. A comparison of the results from the leg and back dynamometer and the cybex machine showed the results to be of a similar magnitude

When the results of the Movement A.B.C. Test are compared with the results of the four strength tests, the results are all significant and reveal that the children with the most serious movement difficulties score poorly in the strength tests and so lack strength when compared with their fellow children. When the results are analysed further and the results of the four strength tests are compared with each of the three component parts of the Movement A.B.C. test, dexterity, ball skills and balance, the results are again significant and again reveal a negative correlation. These results are as anticipated before the study and support the findings of Raynor (1989; 2001) in that they support the hypothesis that strength is a factor in the incidence of D.C.D.

The correlation between the results of the strength tests and the Movement A.B.C. test is lower in the isometric exercises using the grip dynamometer and the leg and back dynamometer than in the isokinetic exercises of Sargent jump and Triple standing long jump and this may reflect the fact that most children are more likely to participate in and therefore improve at, isokinetic exercises than isometric ones. It is unfortunate that no previous research could be found which compared the results of isokinetic strength tests with the Movement A.B.C. test so that these results could be compared with it. However, the greater results and the higher correlation to the results of the Movement A.B.C. test may persuade future researchers to use isokinetic strength tests rather than isometric strength tests in their work.

Of the two isometric exercises the grip dynamometer showed the stronger correlation to the results of the Movement A.B.C. test and this may reflect the observed weakness in the fingers, hands and wrists and the specific difficulties with fine motor skills, such as writing, experienced by those with the disorder and referred to in the literature (Oliveira, Shim, Loss, Petersen, & Clark, 2006). It is unfortunate that no previous research could be found which measured strength in the fingers, hand or wrist so that these results could be compared with it. Writing is such an essential skill for children that further methods need to be found to measure strength in the fingers, hands and wrists. The joints in the fingers, hands and wrists are very flexible and capable of a wide variety of movements and a wide cross-section of tests of strength need to be performed in order to find those affecting children with D.C.D.

The size of the correlation between the three components of the Movement A.B.C. test and the four strength tests vary widely and are difficult to explain. The highest correlation was found between the triple standing long jump, an exercise for the legs and back when compared with ball skills, which involves activities such as throwing a ball against a wall and catching it. This may reflect a skill component in some of the strength tests, which has affected the result. Strength training has an effect not only on the muscles employed in the specific exercises undertaken, but on the body as a whole and on individual body systems and exercise generates a hormonal response which will affect the entire body (Stone, Stone & Sands, 2007). Raynor, 2001 showed that strength exercise prompted improved muscle activation, and improved co-activation, which are neural changes affecting performance. This research did not look at the causes for the improvements in movement skills and strength, recognising that improved muscle activation and muscle hypertrophy are the main causes for gains in strength.

Children with D.C.D. have been found to be reluctant to participate in all forms of physical activity (Ball, 2002). This is unsurprising as nobody wants to show themselves up and we all prefer to take part in activities in which we excel. Participating in physical activity generates, physical, physiological, psychological and sociological changes to the individual. (table 12).

Clearly, considerably more research is required to evaluate strength and its effects on movement skills. There is a need to look at different types of strength and strength in various parts of the body, particularly the fingers, hands and wrists where problems have already been identified and in some of the massive muscle groups where resistance training will generate hormonal release that will promote physiological changes.

The results show that strength is a factor in the incidence of D.C.D. and prompts the question as to whether strength may also be a useful intervention for the condition.

Chapter 6: Study 3: Strength as an Intervention in cases of D.C.D

6.1: Introduction

In 1997, a group of Superintendent Physiotherapists in London came together to discuss the treatment of children with D.C.D. (Lee & Smith, 1998). Parents had learned of the condition in the media, identified similar symptoms in their children and taken the children to the doctor. Initially unsure how to react, the doctors referred the children to either the physiotherapy department or the occupational therapy department. A wide variety of interventions were reviewed and the meeting of Superintendent Physiotherapists was held in order to review these interventions and evaluate them. The research showed that the best method for treating the children with D.C.D. was to undertake an evaluation of their movement difficulties and attempt to identify the specific causes of the condition in each child and then to design a specific and individual resistance training programme based on their assessment. This programme was taught to the parents so that it could be performed at home under parental guidance five times a week and arrangements were then made for the child to perform the programme with the physiotherapist once a week in order to maintain standards and deal with any problems that arose. The individual strength training programmes designed to address the symptoms of children with D.C.D. were shown to improve their symptoms of the disorder by 72%. (Lee & Smith, 1998).

This entire scheme required the involvement of specialist paediatric physiotherapists for several months and was deemed to be too expensive to be funded by the National Health Service in the U.K. and recently the only way to secure this treatment has been through private health care (Lee & Smith, 1998). Despite the considerable research being undertaken into the disorder, no other intervention has come close to achieving this level of success in reducing the symptoms of the disorder and my research is the closest to have come to identifying a universal intervention for D.C.D.

6.2: The History of Strength Training

"That which is used develops, and that which is not used wastes away."

(Hippocrates, 4th century B.C.)

"Whatever doesn't kill me will make me stronger"

(Kanye West, 2008) paraphrased from (Friedrich Nietzsche, 1888)

The value of progressive resistance training in developing a healthy body has long been recognized by young men all over the world. According to Greek Mythology, Milo of Croton (a wrestler from the 6th century BC) trained by lifting and carrying a newborn calf on his back every day. After two years the calf had become a cow and Milo had become a weightlifter. (Pomeroy, Burstein, Donlan & Roberts, 2009). Irrespective of the veracity of the story, it vividly sets out the principles and value of progressive resistance training. Soon a number of scientists became interested in the subject of strength training. Hippocrates (460 BC – 370 BC), the father of modern medicine, recommended it to his patients. (Pomeroy, Burstein, Donlan & Roberts, 2009). Another Greek, Galen of Pergamum (AD 129 – 199) who was given the position of personal physician to several emperors and whose theories dominated and influenced Western medical science for well over a millennium, recommended strength training exercises using an early form of dumbbell called halteres. (Pomeroy, Burstein, Donlan & Roberts, 2009).

The application of the principles of progressive resistance training in strength training programmes has continued to increase through the ages. In 1955, State and Dyson published a book entitled "Weight Training for Athletics". (State, 1955) that introduced the concept of weight training to the wide variety of running, jumping and throwing events in Athletics in order to improve performance. This book started an expansion in strength training in sport that culminated in 1988 in the East German Olympic Committee announcing a policy that required athletes from every Olympic sport except sailing to undertake a programme of progressive resistance training. In 1996 the United States Olympic Committee published a similar policy. (U.S.O.C., 1996)

Traditionally, the lifting of heavy weights has had a reputation for being dangerous and unhealthy (Department of Education and Science, 1980; Rugby Football Union, 1990). Weights are excellent tools for promoting substantial physiological changes to the human body such as improved strength and increased muscle bulk (Stone, Stone & Sands, 2007), but accidents can occur when weights are not secured to bars and when weights are used without spotters (Hamill, 1994). However, whilst the lifting of heavy weights clearly creates the potential for serious accidents to occur, records show that relatively few accidents actually occur and that relatively few people are injured in weights rooms (Hamill, 1994) so that weightlifting is one of the safest sports (Zatsiorski, 2006, p198; Hamill, 1994). Weights rooms are like physiotherapy departments in that they contain much of the same equipment, bars, disks, collars, dumbbells, multigyms and medicine balls The recognition of the potential risks and the enforcement of strict discipline in both the physiotherapy department and the weights room, ranging from dress codes to rules governing personal behaviour and the use of the equipment, have eliminated the risks (Hamill, 1994).

Historically the use of weights by women and young men has provoked considerable debate. It has been said that women will grow bigger and more muscled and that young men will injure their epiphyseal plates and stunt their growth (Zatsiorsky 2006, p.205) and lose flexibility and become musclebound (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004). There is now an almost universal acceptance amongst sports scientists and medical staff that resistance training is safe for all ages and both genders and that all the identified risks from lifting weights can be resolved by high quality professional coaching. A number of high profile, respected bodies have published policy statements on resistance training for young people which confirm these views. (Faigenbaum, Kraemer, Cahill, Chandler, Dziados & Elfrink, 1996; Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee, Frostick, 2004; Behm, Faigenbaum, Falk & Klentrou, 2008) Several of the leading authors on strength training have now published books promoting the subject. (Kraemer & Fleck, 1993; Faigenbaum & Westcott, 2000) It is interesting to note that the person voted the best weightlifter of the 20th century and the first person to clean and jerk three times his bodyweight was a sixteen year old boy. Naim Suleymanov won Olympic Gold Medals in 1988, 1992 and 1996, when he was refereed by the author of this dissertation.

6.3: The Science of Strength Training

The scientific principles upon which strength training is founded are simple and basic but for completeness and in recognition that not all readers will have a sports science background they are set out below.

- Strength
- Strength endurance
- Aerobic endurance
- Speed
- Mobility

(Dick, 2003, p.214)

The components are very closely related and this relationship is illustrated in Figure 2.

The Principles of Training state that in order to improve fitness, all training must be

- Overload
- Specific and is,

- Reversible

(Dick, 2003, p.219)

All strength training programmes must follow these principles in order to increase strength in any person. The strength-based intervention in this research followed these principles.

6.4: Strength and D.C.D.

A comparison of the symptoms of D.C.D. (Section 2.7 on page 34) and the positive effects generated by strength training (Table 12) shows a strong negative correlation and indicates a link between strength and the incidence of D.C.D. and despite the work of Annette Raynor in Australia, (Raynor 1989; 2001) few other researchers have investigated the links any further. It could be claimed that athletes who participate in gymnastic competitions and who display outstanding combinations of complex physical skills have formed new neural links, although possibly of a different type. It is also possible to hypothesise that the movement difficulties experienced by children result from a lack of opportunities to participate in strenuous physical activities as a result of over-protective or overworked parents and that if the children had received these opportunities then the missing neural links may have been formed at that time.

The purpose of this research was to ascertain whether the excellent results achieved by Lee & Smith (1998) could be replicated by physical education teachers or sports coaches already working in schools without the need for specialist paediatric physiotherapists. Secondly, whether the results could be replicated without performing individual assessments of the children or using specialist equipment. If successful, this research could lead to the introduction of the first universal intervention for cases of D.C.D. and an intervention that is both practical and financially feasible.

6.5: Methods

6.5.1: Participants

Participants were 472 primary school children [243 males and 229 females; mean age 9.2 ± 0.9 years, height 1.40 ± 8.9 m, body mass 36 0 ± 9.2 kg]. The children participated in the research at school, in school uniform and school shoes, in the presence of their regular class learning support assistant, in place of lessons. All the children in years 4, 5 and 6 at the six schools (see Appendix 12) within the London Borough of Croydon (see Appendix 11) which responded positively to a letter sent to all the primary schools in the borough, seeking their support for the research, participated.

Prior to the commencement of the research, comprehensive oral presentations were made to the governors and senior staff at each of the schools, setting out the aims and methods of the research. Subsequently, detailed letters (appendix 16) and coloured illustrated leaflets (figure 1) setting out the aims and methods of the research were sent by the schools to the parents of each of the participants and their informed, written consent (appendix 17) secured.

6.5.2: The Tests

6.5.2.1. The Strength Tests

Tests were selected to assess the children's strength which could be undertaken by children with a wide range of strength values and a range of movement skills. Tests were divided between static and dynamic strength and centred on the large muscles of the leg and back where children are reasonably well developed through running and jumping and the area around the fingers, hands and wrists where children with D.C.D. are known to experience muscle laxity and weakness (Oliveira, Shim, Loss, Petersen, & Clark, 2006). The use of static strength tests, such as dynamometers, is discussed in Appendix 8.

The tests selected were:

- Sargent jump (Figures 3 and 4)
- Triple standing long jump (Figures 5 and 6)
- Grip dynamometer (Figures 7 and 8)
- Leg and back dynamometer (Figures 9 and 10)

The figures listed next to each exercise illustrate and describe the techniques of each exercise and set out average performance results for school age children.

6.5.2.2: The Movement A.B.C. Test

All participants were assessed for D.C.D. using the Movement A.B.C. Test (Henderson & Sugden, 1992). The Movement A.B.C. Test is universally recognised as the test for D.C.D. in the United Kingdom, where this research was conducted. All assessments were performed using the officially accredited equipment from Pearson Assessments. The introduction from the test is at Appendix 4. The individual tests that make up the Movement A.B.C. test are at Appendix 5. The record Form for the f of a school-based P.E. programme and the advantages of traditional play and an outdoor environment to encourage exercise the principles of "Feral Play" were devised. These were based on the following views:

Strength may be improved by a range of resistance exercise which "may involve a variety of activities that create work demands on the muscles such as weight- and load-bearing exercise, specific body weight exercises (e.g. running, jumping, hopping) and the use of resistance materials." (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee, Frostick, 2004). As the purpose of the programme was to use only minimal equipment, lifting weights was discounted and as the session was focused on children aged between 8 and 12 years, some of whom were experiencing movement difficulties and some of whom may have been lacking in strength, a decision was made to focus the session on high-intensity running, jumping and hopping. In designing the sessions, careful attention was paid to the application of the principles set out in the United Kingdom Athletics (U.K.A.) campaign entitled "Elevating Athletics" (see Appendix 9). The full programme for the intervention is set out in Appendix 10. The intervention was designed as two 30-minute sessions each week for six weeks. Recognising that children will interrupt classes by seeking toilet breaks, drinks breaks and first aid for insignificant injuries, none were permitted. The children were all required to use the toilet and drink water whilst changing into and out of their sports kit, as no healthy child should need toilet or drinks breaks more than once in half an hour. Children reporting injuries that were not visible and relating to incidents that were not witnessed by staff were encouraged to continue playing and offered first aid after one minute, by which time the child had forgotten the injury. No adult was permitted to encourage a child other than by setting targets and recognising achievement. These rules mimic the "Feral Play" in which children indulge when left to their own devices, without adult supervision.

The sessions were well received by the children and no complaint was raised about the repetition of the same progress each week for six weeks. The competitiveness of the sessions provided the motivation and satisfaction that each child required in order to continue the training and complete the programme. It is accepted that if the programme was to be extended beyond six weeks that the sessions would have to be varied in order to provide the continued variety required by the children.

6.5.4: Experimental design

Arrangements were made for the testing to be performed out of doors, weather permitting and in a school hall or gymnasium if it was not. This allowed a positive, encouraging, competitive atmosphere to develop. The tests were undertaken in order, with each child permitted three attempts at each exercise, with all results being recorded and the best result being used.

Children from four of the schools undertook the intervention and for comparison purposes the children from one school, chosen at random, were selected as a control group and did not undertake the intervention.

6.5.5: Measurements

6.5.5.1. The Strength Tests

- Sargent jump (Figures 3 and 4)
- Triple standing long jump (Figures 5 and 6)
- Grip dynamometer (Figures 7 and 8)
- Leg and back dynamometer (Figures 9 and 10

The figures next to the exercises describe and illustrate the technique for that exercise and set down mean performance results for children of school age.

6.5.5.2: The Movement A.B.C. Test

All assessments were performed using the officially accredited kit from Pearson Assessments. All scores were calculated using the published record form a copy of which is shown in Appendix 6.

6.5.6: Apparatus

6.5.6.1. The Strength Tests

Sargent Jump Test

The Sargent jump test was measured using the same digital jump meter on all occasions (TKL 5106 jump meter; Takey, Tokyo, Japan). The reported precision of the device was 1 cm. When performing the test, the subject stood on the platform with his or her feet apart at a comfortable distance of hip width for balance. The subject was instructed to flex at the knees and then to extend the knees vigorously and to reach as high as possible. Each subject performed the test three times allowing a one minute rest period between measures.

Triple standing long jump Test

The triple standing long jump was measured using a standard metric tape measure. Each subject was instructed to stand behind a line set down on the ground in front of them. The subject was then instructed to jump two-footed as far as he or she could three times. Each subject performed the test three times allowing a one minute rest period between measures.

Measurement of grip strength.

Grip strength was measured using the same digital dynamometer on all occasions (TKL 5401 Grip-D; Takey, Tokyo, Japan). The reported precision of the device was 0.1 kgf. When performing the dynamometry, subjects maintained the standard bipedal position during the entire test with the arm in complete extension moving from overhead to the side of the leg, and did not touch any part of the body with the dynamometer except the hand being measured. Each subject performed the test three times with his or her preferred hand allowing a one minute rest period between measures.

Measurement of leg and back strength.

Leg and back strength was measured using the same digital dynamometer on all occasions (TKL 4502 Leg-D; Takey, Tokyo, Japan). The reported precision of the device was 0.5 kgf. When performing the dynamometry, the subject stood on the platform with his or her feet apart at a comfortable distance of hip width for balance and with his or her hands grasped at each end of the bar. The subject was instructed to flex at the knees and to keep the back straight and then to extend the knees as smoothly and as forcefully as possible. Each subject performed the test three times allowing a one minute rest period between measures.

6.5.6.2: The Movement A.B.C. Test

All assessments were performed using the officially approved kit from Pearson Assessments.

6.5.7: Statistical analysis

Applying SPSS version 10.0 for statistical analyses, differences of two-tailed $p < 0.01$ were considered as statistically significant. All data were shown as means with standard deviations (means ± SD). Paired t tests were used to compare pre-intervention and post interventions results in both the four strength tests (the Sargent jump, the triple standing long jump, the grip dynamometer and the leg and back dynamometer) and the Movement A.B.C. test.

6.6: Results

When the results of the Movement A.B.C. Test and its components are compared pre-and post- intervention, the results show a significant reduction in each of them for the intervention group, indicating an improvement in movement skills pre-and post intervention. These improvements in movement skills were anticipated.

Table 6A: Result of Paired t test for Comparison of Movement A.B.C. Tests from Pre- to Post- Test in the Intervention Group.

	Pre-intervention		Post intervention				
Statistics / Tests	$\bar{x}$	± SD	$\bar{x}$	±SD	M.D.	t	df
Dexterity	9.86	4.41	8.41	4.33	1.44	6.86**	340
Ball skills	2.48	2.48	1.45	1.97	1.02	8.82**	340
Balance	8.14	5.43	7.45	5.61	.68	2.31*	340
Movement A.B.C. Test Score	20.48	8.69	17.32	8.76	3.16	8.66**	340

** $p<.01$
* $p<.05$

When the results of the Movement A.B.C. Test and its components are compared pre-and post- intervention, the results show no significant change for the control group in the Movement A.B.C. Test and two of its component areas, dexterity and ball skills, as anticipated. The changes pre- and post-intervention in the third component, balance is significant, but negative, reflecting a loss of balance pre-and post-intervention, which had not been anticipated and which cannot be explained.

Table B: Result of Paired t test for Comparison of Movement A.B.C. Tests from Pre to Post Tests in the Control Group

	Pre-intervention		Post intervention				
Statistics / Tests	$\bar{x}$	± SD	$\bar{x}$	±SD	M.D.	t	df
Dexterity	9.20	4.53	9.14	4.51	.006	.28	130
Ball skills	.78	1.28	.89	1.66	-.10	-1.35	130
Balance	5.22	3.65	6.86	3.5	.36	2.70**	126
Movement A.B.C. Test Score	17.28	6.70	16.95	6.67	.33	1.26	126

** p<.01

When the results of the four strength tests are compared pre-and post-intervention, the results for the intervention group show significant improvements of approximately 10% have been made in two of the tests, the triple standing long jump and the grip dynamometer. These are in line with anticipated results. In the other two tests, the Sargent jump and the leg and back dynamometer the changes pre- and post- intervention were found not to be significant. The initial results of the leg and back dynamometer were well above the normal range and this may have affected any changes made during the intervention. The children complained of experiencing technical difficulties whilst undertaking the Sargent jump and the results may reflect these difficulties.

Table 6C: Result of Paired t test for Comparison of Strength Tests from Pre- to Post- Test in the Intervention Group

	Pre-intervention		Post intervention				
Statistics / Tests	$\bar{x}$	± SD	$\bar{x}$	±SD	M.D.	t	df
Sargent jump	33.46	± 8	33.07	6.37	.38	1.11	340
Triple standing long jump	4.07	± .69	4.41	.75	-.33	-.58**	340
Grip dynamometer	15.35	± 4.33	16.81	4.87	-1.45	-11.92**	340
Leg and back dynamometer	48.16	± 13.44	47.33	12.86	.82	1.37	340

** p<.01

When the results of the four strength tests are compared pre-and post-intervention, the results for the control group show no significant changes in two of the exercises, the Sargent jump and the grip dynamometer, as anticipated. In the triple standing long jump the improvement was significant, but negligible at approximately 1%. In the leg and back dynamometer there was a significant improvement of approximately 4%, which was not expected and cannot be explained.

Table D: Result of Paired t test for Comparison of Strength Tests from Pre to Post Test in the Control Group

	Pre-intervention		Post intervention				
Tests \ Statistics	$\bar{x}$	± SD	$\bar{x}$	±SD	M.D.	t	df
Sargent jump	33.85	± 7.84	33.74	7.72	.10	.79	130
Triple standing long jump	4.65	± .76	4.70	.78	-.004	-3.72**	130
Grip dynamometer	17.10	± 4.7	17.13	4.7	-.003	-.36	130
Leg and back dynamometer	43.91	± 12.92	45.58	13.62	-1.66	-5.19**	130

** $p<.01$

6.7: Discussion

The strength training intervention designed by Lee & Smith (1998) is the only published attempt at a universal intervention for children with D.C.D. and recorded a 72% reduction in the symptoms of the condition. The requirement for an extended individual assessment of each child by a specialist paediatric physiotherapist made the cost of the treatment prohibitive and it is not currently policy for either the National Health Service or private healthcare providers to supply this treatment for children with the condition and the most popular interventions currently rely on repeated practice of the skills that children with D.C.D. find the most troubling. (Ball, 2002; Boon, 2002) Despite the success of the strength programme, the fact that twelve years has lapsed since the publication of the research and that a great deal of other research has been conducted into the disorder and its treatment, no further study has been conducted into the area to ascertain whether the results are capable of being reproduced at a lower cost. The primary purpose of this research was to ascertain whether the excellent results achieved in Lee and Smith, 1998 could be replicated by physical education teachers or sports coaches already working in schools without the need for specialist paediatric physiotherapists employed in the original research. The second objective of the research was to ascertain whether the results could be replicated without performing individual assessments of the children or using specialist equipment.

A simple programme of resistance training exercises, including running, jumping and hopping, based on the U.K. Athletics programme "Elevating Athletics" applying the basic principles of training and requiring no specialist equipment or skilled supervision, was employed twice each week for six weeks. This meant that the session could be performed at any school possessing a gymnasium bench and that any P.E. teacher or sports coach could supervise the session. In this way the programme becomes universally available to all children. Following this strength intervention the scores in the Movement A.B.C. test in the intervention group revealed a significant reduction, reflecting an improvement in movement skills. The scores in the control group revealed no such significant reduction, thereby eliminating the effects of any external factors. Clearly, the primary purpose of this research, to ascertain whether the excellent results achieved in Lee and Smith (1998) could be replicated by physical education teachers or sports coaches already working in schools without the need for specialist paediatric physiotherapists employed in the original research, has been achieved. The second objective, to ascertain whether the results could be replicated without performing individual assessments of the children or using specialist equipment, has also been achieved.

As each exercise programme employed in Lee and Smith, 1998 was individually tailored to the needs of the child, no detail was published of the programmes, so a direct comparison between those programmes and the one employed in this study, is impossible. However, when comparing strength training programmes it is common to consider the F.I.T.T. Principles of frequency, intensity, time and type (Walker, 2004). In Lee & Smith (1998) the intervention lasted for eight weeks, rather than the six weeks that was imposed on this study by school holidays at the end of each half term. Lee and Smith, (1998) monitored progress throughout the research and found that the greatest gains occurred between six and eight weeks of the trial starting and future research may benefit from the longer duration for the strength intervention. Whilst most adult programmes last for six weeks, the fact that the children do not benefit from secreting testosterone may mean that they require additional time to make the necessary gains in strength. The eight week period of the intervention will cause many researchers problems if they recruit their subjects from schools where most half terms are less than seven weeks long and the children are unavailable on holiday between half terms. In Lee and Smith (1998) the children undertook their strength training programme six times each week, five times with parental guidance and once with their physiotherapist and took just one rest day each week. In this study, due to difficulties in securing access to the children, they completed their strength training programme just twice per week. Although significant strength gains were made in the Triple standing long jump in this study the potential for even greater gains clearly exists, provided that daily access to the children can be arranged. The lack of published details of the programmes employed in Lee and Smith, 1998 prevent a direct comparison between the intensity of that and the present study. The intensity of the strength intervention in this study was relatively high at the start, when the children were quite unfit. As the study progressed the intervention increased in intensity but not as quickly as the children improved their fitness, so the potential exists to increase the intensity towards the end of the programme.

A similar lack of data from Smith and Lee, 1998, prevents a comparison of the types of exercise employed in the two studies, but it is likely that employing the use of weightlifting exercises would be likely to increase the intensity and improve the focus of the intervention.

In addition to satisfying the objectives set for it, this research has debunked some popular myths which currently surround D.C.D. When Geoff Brookes, a Vice Principal in charge of Integration and a Special Educational Needs Co-ordinator, attempted to set down the seven greatest myths surrounding D.C.D., he settled upon:

> Dyspraxic children are lazy
> Dyspraxic children are stupid
> Dyspraxic children just need to work harder
> Dyspraxic children are naughty and disruptive
> Dyspraxic children are created by bad parenting
> Dyspraxic children just need to concentrate a bit more
> Dyspraxic children will eventually grow out of it.
>
> (Brookes, 2007, p.12)

At a time when the benefits of a healthy lifestyle, including regular exercise, are almost universally recognised, children with D.C.D. are reluctant to participate in physical education classes or in any other form of sporting activity (Kirby & Drew, 2003). The reason for this reluctance is the embarrassment that the children feel at their lack of sporting prowess and the fact that their lack of movement skills may result in an accident (Macintyre, 2001). This lack of motivation and reluctance to exercise means that the children are lazy and this research has shown that children with D.C.D. do need to work harder at a strength training programme in order to substantially reduce the symptoms of D.C.D. from which they suffer. Faced with strenuous resistance to any invitation to participate in physical exercise, it is very easy for a parent or teacher to permit children with D.C.D. to avoid all involvement in sport, but in fact the need for children with any type of disability to participate in exercise is greater than in the "normal" population (Geutz, 2007).

A list of symptoms for those with D.C.D. has been produced.

Health Risks Associated with D.C.D.

Type 2 diabetes

Cardiovascular disease

Metabolic syndrome

Dyslipidemia

Polycystic ovarian syndrome

Psychological

Pulmonary hypertension

Neurological

Orthopaedic

Advanced maturation

Renal

(Vargas 2006 in O'Donohue, et al., 2008, p.33)

Relative risks of health problems associated with obesity

Greatly increased	Moderately increased	Slightly increased
Type 2 diabetes Gallbladder disease Dyslipidaemia Insulin resistance Breathlessness Sleep apnoea	Coronary Heart Disease Hypertension Osteoarthritis (Knees) Hyperuricaemia and gout	Cancer Reproductive hormone abnormalities Polycystic ovary syndrome Impaired fertility Low back pain Anaesthetic risk Fetal defects associated with maternal obesity

(WHO, 1998)

The two lists of symptoms have many similarities with half the items in the first list appearing also in the second. Perhaps, the health risks associated with D.C.D. simply reflect the failure to participate in exercise rather than a direct correlation with D.C.D.

This study has shown that a simple, universal intervention does exist and is effective in improvement skills. By working harder at a strength intervention children are able to improve in the wide range of movement skills assessed in the Movement A.B.C. Test.

Chapter 7: General Discussion and Conclusion

7.1.: Introduction

D.C.D. is a condition whereby children are affected by a range of movement difficulties that affect their ability to perform the tasks of daily life. (Kirby & Drew, 2003) The condition has been researched by a wide range of specialists from education and medicine for almost ninety years, but only very rarely by experts from sports science, sports coaching or movement science. Research papers revealing that strength was a factor in the incidence of D.C.D. (Raynor, 1989; 2001) and that strength training provided a useful intervention for those with the condition, (Lee & Smith, 1998) appear to have been overlooked in recent years. The present study set out to review the state of current knowledge about D.C.D. from a sports science, sports coaching or movement science viewpoint and to identify research opportunities in D.C.D. that are available to experts in these areas.

A thorough and exhaustive review of the literature identified the first problem for researchers into D.C.D., the lack of an accurate test to identify those with the condition. Whilst there are unlimited tests by which children's movement skills may be assessed, none identifies those with the condition in a manner than satisfies the experts. (Sugden & Wright 1998) This research set out to identify alternative methods to identify the condition. Research showing that strength is a factor in the incidence of

D.C.D. was published by Rayner (2001) but it has not been taken further. The present study set out to investigate this relationship further. Research showing that a 72% improvement in the symptoms of D.C.D. could be produced by personalised strength training interventions (Lee & Smith, 1998) have been discontinued due to the high costs involved, but no further research has been undertaken to ascertain whether similar results can be produced without the high costs.

7.2: The Movement ABC Test

The Movement A.B.C. test (Henderson & Sugden, 1992) is now almost twenty years old. In that time it has performed an important role in assisting doctors and teachers to identify those children experiencing severe movement difficulties and most in need of professional support. The test has also permitted researchers to agree the method used to identify subjects for their work and to increase the body of knowledge on all aspects of the disorder. However, the Movement A.B.C. test has been criticized for being inaccurate, expensive, time-consuming and inconvenient. Sugden, one of the authors of the test who commented that the most accurate test for those with D.C.D. was to ask the children's class teacher (Sugden & Wright 1998, p.53). A comparison of the Movement A.B.C. Test, favoured in the U.K. and the Bruininks Oseretsky Test, favoured in the U.S., found significant differences in the results and a correlation of only 0.80, that neither test was better than the other, but rather that the best results were achieved by undertaking both tests. (Crawford et al., 2001). As each test takes two hours per participant it is clear why this suggestion has not been taken up. The variation in these results are reflected in different children being diagnosed with the condition in different places, according to which test is applied and this can cause the affected children serious consequences. A considerable number of scientific advances have been made in the last twenty years and renewed efforts should now be made to identify a new test capable of generating improved accuracy and increased reliability, validity and objectivity and improved convenience to users thereby introducing the possibility of universal testing of children for the condition. In view of the fact that there is no essential symptom and no cause for the condition then any new tests will have to focus on the performance of an exercise with which all children are equally familiar or unfamiliar.

Substantial difficulties exist in defining a reliable and valid test for a condition that lacks specific symptoms. D.C.D. is now universally accepted as a condition adversely affecting the movement skills of 5% of all children, (Henderson & Sugden, 1992) but no exhaustive list of symptoms of the condition exists and no symptom is essential for a diagnosis. (Kirby & Drew, 2003) Indeed, the symptoms are affected by brief and transient changes to the child's health and level of fatigue (Ball, 2002). Any new assessment tool to identify the condition must assess a child's performance in a range of movement skills and then define a method of scoring these performances in order that they may be combined and the children with the condition identified. Recent advances in technology have permitted new assessment methods that were not previously possible. These methods are likely to be cheap, simple to use, objective and small. The potential now exists for a universal test that could be undertaken by all children thereby avoiding the risk of teachers missing some children with the condition.

This research focused on the application of Approximate Entropy to identify children with D.C.D. Approximate Entropy is an emerging technology that has been employed with some success in gait analysis in older subjects. Children were tested using the Movement A.B.C. Test and then again using the Entropy device and the results of the two tests were compared. The results were inconsistent and on this basis the Entropy test is not producing valid and reliable results and cannot yet be considered as a satisfactory replacement for the Movement A.B.C. Test. The Entropy Test results did, however, show an interesting sensitivity and it may be that as the technology improves further research may be undertaken with better success. The practicality of the Entropy test also highlighted the advantages available should such an electronic test be able to produce valid and reliable results become available. The Entropy Test was very quick and easy to administer and required little space or equipment and no trained staff. Mass production of the device would reduce the cost of the test and these factors, taken together, could potentially enable universal testing of all children at an early age.

Without an accurate method of identifying those with D.C.D. the quality of the results of all research into the condition is adversely affected, to the extent that all current research into D.C.D. will have to be re-evaluated when an accurate test is established. The design of a universal, reliable, valid and objective test must become the highest priority among those researching the condition.

7.3: Strength as a factor in the incidence of D.C.D.

Raynor (1989; 2001) shows that strength is a factor in the incidence of D.C.D., but although the papers are now approximately 10 and 20 years old and strength has now become more of a subject for academic study and recognised as a fundamental constituent in human performance (Stone, Stone & Sands, 2007; Zatsiorsky, 2006), no further research in the area was found.

Educationalists have identified that children are engaging in less activity and that the nature of the activity that they undertaking is changing.

> There is a growing concern that children are becoming more sedentary in their adolescence, and scenarios predict enervated health later in life due to an inactive adolescence. (Anderson et al. 1998, Heggebo 2003).
>
> (Fjortoft, 2004 p.22)

> The natural environment has traditionally been a site for play and physical environment for many children, but many modern societies seem to have neglected the value of such environments for the development of children and adolescents. A generation ago,

> children had access to wild lands and used them for exploring, challenging and exercising the skills needed to master a challenging landscape and unforeseen situations. Today, children's physical play environments seem to be declining (Esbensen 1990, MMI 1997).
>
> (Fjortoft, 2004 p.22)

> Children's play also is more vigorous outdoors than indoors
>
> (Henniger 1980 IN Fjortoft, 2004 p.29)

The changes in the quantity and quality of exercise undertaken by children has been shown to have affected their opportunities to improve their movement skills.

> Natural environments represent different play opportunities for children. The rough surface provides movement challenges, and topography and vegetation provide a diversity of different designs for playing and moving.
>
> (Fjortoft, 2004 p.22)

The work of Fjortoft was also reflected in the type of activity undertaken and a decision was taken to focus on Functional Play according to the following definition:

> Physical Activity Play
>
> Play behavior that constituted physical activity was observed and classified in three categories (Frost 1992)

1. Functional Play (physical play activities: identified and categorized in subgroups such as running and tumbling, climbing rocks and sliding ropes, climbing tress, and playful skiing).
2. Constructive play (building huts and shelters and playing with loose parts, sticks, cones, pebbles, etc.).
3. Symbolic play (role play, dramatic play and social play like house play, pirates etc.).

(Fjortoft, 2004 p.27)

Recognising the problems associated with making a noise in classroom blocks and the restrictions on children within school buildings and in the presence of staff, every opportunity was taken to remove the children from classrooms to nearby play areas or fields and to focus on functional play.

Previous research into the effect of strength on the incidence of D.C.D. has focused on isometric leg strength, (Raynor, 1989; 2001) whereas few children actually undertake isometric exercise until they reach their late teenage years, preferring instead to run, hop and jump, which is more isotonic in nature. Although this lack of strength has occurred all over the body it has been particularly noticed in the fingers, hands and wrists (Oliveira, Shim, Loss, Petersen, & Clark, 2006) which are used in the fine motor skills such as writing and drawing.

Strength may be improved by a range of resistance exercise which "may involve a variety of activities that create work demands on the muscles such as weight- and load-bearing exercise, specific body weight exercises (e.g. running, jumping, hopping) and the use of resistance materials." (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee, Frostick, 2004). My study compared the results of a group of schoolchildren in the Movement A.B.C. and its three components with their results in four strength tests, the Sargent jump, the triple standing long jump, the grip dynamometer and the leg and back dynamometer. The results showed a significant correlation between the weaker children and the incidence of D.C.D. This confirms the results produced by Rayner and extends their application to isotonic as well as isokinetic exercises.

The study also looked at the work of Jonnson on Teaching Games for Understanding (TGfU) and attempted to include the opportunities for individual learning experiences for students and applied these into the principles of Feral Play.

> Educators are challenged to provide learning experiences for children that are realistic and which present opportunities for potential performance solutions to be generated by learners themselves
>
> (Jonnson, 2006)

7.4: Strength as an Intervention in D.C.D.

Attitudes to resistance training have changed considerably in recent years. There is now a general consensus that it is safe for all sections of the population including men and women, young and old, to participate in strength training, (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004) and that strength training is necessary in order to maximise sporting performance in almost every sport (U.S.O.C. 1996). A number of policy documents have been published in order to express these views. (Stratton, Jones, Fox, Tolfrey, Harris, Maffulli, Lee & Frostick, 2004) Strength training has been shown to improve a range of physiological and psychological variables (Table 12) and previous research had shown that resistance programmes prepared by paediatric physiotherapists and based on extensive observations of the subjects and regularly supervised by the same physiotherapists had reduced the symptoms of the condition by 72%. (Lee & Smith, 1998) This research was designed to ascertain whether similar results could be achieved by a universal intervention using the equipment and staff generally available at most schools. The strength intervention programme involved simple exercises such as running, jumping and hopping and applied the principles of training in order to eliminate weakness by improving strength and thereby to reduce movement difficulties. It should be stressed that as this is a strength improvement programme, the principles of overload apply and the participants will need to undertake sufficient exercise of satisfactory intensity in order to promote the increases in strength necessary in order to improve their movement skills. It is for this reason that the principles of Feral Play were set out on page 72. Feral Play imitates the traditional style of play in which children run wild, but whilst taking few risks. The session plan sets down a vigorous programme designed to increase muscular strength and improve movement skills.

The Session Plan

Session 1

20 metre relays

a) 1 x running

b) 1 x right foot hopping

c) 1 x left foot hopping

d) 1 x bunny hopping with two feet together

e) 1 x bunny hopping touching the ground between hops.

f) 1 x sprint race

4 x 10 each hand crushing the tennis ball.

Session 2

Bench straddle jumps (stand on the bench, jump down onto the floor straddling the bench, sit on the bench, and then jump back on the bench).

Repetitions = Week Number x 4.

Repetitions = Week Number x 6.

Repetitions = Week Number x 10.

Repetitions = Week Number x 15.

Repetitions = Week Number x 20.

The results of the pre- and post- intervention Movement A.B.C. Tests showed a significant reduction in the movement difficulties pre- and post-intervention and confirmed the finding of Lee & Smith (1998). A number of methods for improving these results exist, by increasing the duration of the intervention, the number of sessions during the week at which the intervention is undertaken, the duration of each training session at which the intervention is undertaken and the intensity of each session, although the desirability of increasing each of thee options needs be carefully consideration.

7.5: Conclusions from the research

It is clear that sports science, including sports coaching, movement science and strength and conditioning, has a great deal to offer research into D.C.D. These subjects are all performance related and although the experts in these subjects generally focus on elite performance, there are clearly advantages for them to use the knowledge and experience derived from elite performance for the benefit of young children with movement difficulties. It should not be a surprise that experts in education and medicine have not responded immediately to research papers showing strength to be a factor in the incidence of D.C.D. and a useful intervention in cases identified. The recent expansion of academic study from Physical Education to sports science and then to sports coaching, strength and conditioning and movement science means that the time is now right for further research and for forgotten lines of research from the past to be re-opened.

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Appendix 1

The First Reference to Clumsy Children

Extracts from Reading, Writing and Special Problems in Children
By Dr S.T. Orton, Consultant Neurologist
Published by Norton, New York (1937)

The book is divided into three sections:

1. Language Losses in the Adult as the key to the development disorders in children;
2. Certain disorders in the development of language in children;
3. Interpretation and treatment of certain disorders of language in children.

Section 2. Certain disorders in the development of language in children

"5. Developmental Apraxia (Abnormal Clumsiness)

The fifth group of cases to be discussed is that of developmental apraxia (congenital apraxia). The recognition of this type of individual goes back at least to Galen who spoke of some children as being "ambilevous," that is, doubly left-handed. Except for the unjustified implication as to the general unskillfulness of left-handers, this characterization fits the situation well. These children seem to be equipped with a lack of skill on both sides comparable to that of the left hand in a strongly right-handed person. The inability in this condition is for the carrying out of any complex trained movements whether they be of hand, foot, or body, and the question might be raised as to why this syndrome is included in a description of the developmental language delays. Two considerations have led to such inclusion. First, an acquired apraxia may result in the adult from a unilateral brain lesion, providing that lesion affect the dominant hemisphere, thus placing the control of highly skilled movements in the same group physiologically as the various language functions; and second, the difficulty of learning complex movements which characterizes the apraxias may extend to the motor patterns of both speech and writing as well as to the movements of the body and the extremities, and hence lead to specific language disorders in the motor or expressive field.

As stated above, there is a notable absence of skills on either side in these children and usually in spite of extended training there is a strong suggestion of a very close balance between the two hands. Motor tests often also show an amphiocularity or a lack of ability in monocular sighting by either eye. Such children are often somewhat delayed in learning even the simpler movements such as walking and running, and have great difficulty in learning to use their hands and to copy motions shown to them. They are slow in learning to dress themselves and are clumsy in their attempts to button their clothes, tie their shoes, handle a spoon, and in other simple tasks. One such boy recently studied had been slow in learning to walk and was awkward in his gait. He had mastered with some effort the riding of a three-wheel velocipede but the bicycle proved too much for him. Roller skating was likewise impossible for him as was baseball and almost all of the games of boyhood. In his case, his difficulty in learning motor patterns extended also to speech and writing. His speech was clipped and slurred, and although he could make all the sounds necessary for most words, his ability to blend them into a word and to use them properly in speech was very poor.

In writing, neither hand had very much to recommend it and much effort over several years had failed to produce an acceptable penmanship. Although twelve years of age and equipped with normal intelligence, his motor patterns, on either side, were those of a much younger child and showed a marked intergrading."

Section 3. Interpretation and treatment of certain disorders of language in children

"5. Developmental Apraxia

Among the children finding unusual difficulty in learning patterns of movement is to be found an occasional individual who is a shifted left-hander and who never has been successful in acquiring skills on the right although this may be the side used extensively. Where history and motor tests indicate this to be the case a retraining of the left hand may do much to offset the unskillfulness. A much more intricate problem is presented by the majority of apraxic children, however, since their unskillfulness extends to both hands they are "doubly left-handed" and often amphiocular as well-and no latent abilities are uncovered by tests in either the right or the left side. The number of cases which we have studied in which apraxia was the outstanding symptom is not large and our facilities for extended experiments in training were not of the best but a few observations and results nevertheless seem worthy of record while awaiting the opportunity to extend this line of research with additional cases and experiments. Our attention has been directed to attempting to determine very simple patterns of movement over which the child has a reasonable mastery, and gradually combining these simpler patterns into more complex and difficult ones. Here again we have been guided by the belief that it is in such recombinations of simple movements that the crux of the apraxic child's difficulty rests.

At times the motor inaptitude seems to involve movements of the body as a whole including such factors as balance and gait and not merely the more complex movements which underlie manual dexterity. These children are often quite proficient in activities such as swimming and horseback riding where the body is supported without so great a need for equilibration, but the gross movements of the body in such acts as walking, running and jumping are very poorly executed. This was the case with one girl of about six years of age who walked with a very clumsy stride and who could "never walk up stairs without stumbling on at least every other step." She also had tried to learn some very simple dance steps from one of her teachers but her efforts in this were far from a reproduction of the demonstrated pattern. To train the stepping movements for stair climbing, two by ten inch wooden blocks were employed and the child was taught to put only the ball of the foot on the block and then to raise the body enough to bring the toe of the other foot clear when it was swung forward. This was practiced on one foot at a time before a second block was added and progressional alternating steps were permitted. Next, the height of the blocks was increased to four inches and gradually a very satisfactory result was attained on the stairs. It may be remarked in passing that the learning of many of our skilled acts depends on visual observation of the movements of others and that these visual models must then be retranslated into kinaesthetic-motor patterns. With this idea in mind, experiments were tried with the dance steps with both the child and her teacher standing before a large mirror so that the teacher's movements were reflected as on the same side in which the child was attempting to copy them, and this procedure was much more successful than were attempts at vis-a-vis imitation.

It is common to assume that the simple, largely reo flex patterns of movement which enter into walking and running, for example, are sufficiently well acquired by the child without training so that in the more difficult sports, such as tennis, attention need be given only to the special instruction for that game and this, of course, is true of most children. In those with a measure of apraxia in their make-up, however, this assumption is not justified and much better headway might be made by spending some time teaching the child how to run and turn and stop without losing balance, before specific training in the sport is begun.

In those apraxic children whose clumsiness is expressed chiefly in learning manual skills, one symptomatic indication would seem to be to raise the level of dexterity in one side above that of the other by games such as those mentioned above, and since no superiority can, as a rule, be demonstrated on either side in these children, we are left with a choice as to which side shall be trained. Under such circumstances our advice has favored the right hand to conform with the more generally used pattern of the community at large.

One issue not infrequently raised by parents of these children is that of what their reaction should be toward the excessive awkwardness which leads to spilled food at table, upset milk glasses, etc. It often helps the parent to understand that this condition may be a real disability and not merely excessive carelessness. Obviously, punishment or scolding for such accidents is not just nor does it seem to be efficacious since too much attention paid to the mishaps may increase the difficulty. How this operates is not clear but it seems to be related to the greater trouble inherent in the propositional or effortful element already noted in the writing disability cases and those with a motor speech delay and which comes into its fullest flower in stuttering. Possibly the best attitude for the parents to adopt is that of tolerant amusement toward each episode but with careful observation of the faulty movements, looking toward sympathetic instruction for their correction.

A considerable measure of feeling of inferiority seems to be unavoidable in the apraxics, especially as these children grow to the age when they enter active physical competition where their limitations must be rather piteously exposed. While the acquisition of skills is arduous for the apraxic, almost any technique can be mastered with sufficient application and practice, and sometimes slow but punctilious training in some one sport or manual craft will serve to compensate largely for the more general awkwardness. Thus, in one of the writer's patients, a question about tennis brought up some obviously rather painful recollections of experiences on the court but the child was prompt to volunteer at this stage that she had by persistence learned to sew quite well. She later brought in a sample of her work which showed almost meticulous neatness and accuracy in stitching. Fortunately, many of the apraxic cases are quite successful competitors in their scholastic work and this is frequently a source of satisfaction which serves as a recompense for their failures in athletics and manual work." (Orton, 1937)

Appendix 2

The Second Reference to Clumsy Children

BRITISH MEDICAL JOURNAL Page 1665
LONDON SATURDAY DECEMBER 22
"CLUMSY CHILDREN

It is a sobering thought that many of the things for which a child gets into trouble at school are not always his own fault. He gets into trouble because of bad behaviour, which is due partly to inherited personality, partly to errors of management at home, and partly to "original sin." Unpopularity at school is largely due to the same causes. He gets into trouble because of neglect of homework, and this may be entirely his own fault: not infrequently, however, it is his parents' fault, in that they have shown no interest in seeing that the work is done before he is allowed to indulge in other pursuits. He does badly at school because he has been unnecessarily kept off school by an overprotective mother, by a mother who wants his company at home or help in the housework, or by a family doctor who has not, quite balanced in his own mind the harm it will do if he misses school and the harm it will do if he goes to school against the doubtful advantages of staying at home. He gets into trouble for fidgeting, for poor concentration, and for poor performance. The commonest cause of this is a low level of intelligence in - relation to the class requirements, and again he cannot be blamed for that. Recent work has suggested other causes for this sort of trouble at school.

A.L.Annell,[1-3] of Uppsala, has written several papers about the so-called clumsy child, the child who is awkward in his movements, poor at games; hopeless in dancing and gymnastics, a bad writer, and defective in concentration. He is inattentive, cannot sit still, leaves his shoelaces untied, does buttons wrongly, bumps into furniture, breaks glassware, slips off his chair, kicks his legs against the desk, and perhaps reads badly. Some, she says, tend to make large sweeping movements when writing, to write with the whole body, with the tongue protruding and travelling from one side of the mouth to the other. Some are worse when they are anxious and being watched. Reprimands merely make the child worse and lead to a variety of behaviour problems-truancy, insecurity, aggressiveness, bullying, encopresis, enuresis, and day-dreaming. He cannot help it. Annell regards the problem as largely one of delayed maturation: the child shows at the age of 8 or 10 many of the features of the normal 3- or 4-year-old. Recovery is usually spontaneous.

In Groningen, Holland, H. F. R. Prechtl and C. J. Stemmer[4] have described another group of clumsy children. They have poor concentration in relation to their I.Q., they do badly at school, they are awkward in movements, and show characteristic sudden twitching movements of the limbs, head, and trunk. These are not tics. The authors use the term "choreiform syndrome" and relate this to anoxia at birth and to poor condition at birth. The result of these fascinating and most painstaking prospective studies, at present in progress, will provide an invaluable insight into the aetiology of some of the problems of schoolchildren.

In Great Britain J. N. Walton, E. Ellis, and S. D. M. Court at Newcastle upon Tyne have described a further group of five clumsy children. They were in trouble at school and thought to be mentally subnormal. They were awkward in dressing, feeding themselves, walking, writing, drawing, and copying. None of them showed neurological signs pointing to disease of the pyramidal tracts, cerebellar tracts, or extrapyramidal system. Careful psychological testing elicited several notable responses. These children found it difficult to fit shaped blocks into holes; their writing showed frequent reversals; they found it difficult to copy simple shapes; they had difficulty in distinguishing right from left; speech in some was poor; they could not catch a ball; they could not relate one part of the body to another. Four of the five showed crossed laterality. In all there was a striking difference between the high or normal score on the Wechsler verbal scale and the poor performance on the performance scale. The authors considered their patients had apraxia, defects of tactile appreciation or recognition, disturbance of body image, or agnosia. The defects were best recognized by asking them to dress and undress, to draw everyday objects, to copy letters or figures, to make designs with blocks, to place shaped objects through holes, and by the Wechsler tests. They noted the similarity between these children and those with Gerstmann's syndrome, in which there is a lesion in the parietal lobe.

In a recent conference on child neurology at Oxford, held under the auspices of the National Spastic Society, R. S. Illingworth described another group of clumsy children and showed some of the features in a film. Several of these were examples of minimal cerebral palsy. They all showed a normal gait but were referred because they were falling frequently, writing badly, were slow with their hands, or were unable to run properly. Most of them showed notable unsteadiness in standing on one leg. Some had slight athetosis, some showed minimal signs of the spastic form of cerebral palsy. All had been thought to be normal, but all had been in trouble for their clumsiness. The I.Q. in all was normal and in some superior.

It would seem that the causes of this condition are diverse. In some it is due to delayed maturation of part of the nervous system. Just as some children are late in learning to walk, talk, or acquire control of sphincters others are late in acquiring normal control of their hands, normal spatial appreciation, and so normal writing, reading, and other skills. What is normal at one age is not normal at another. In some there are minimal signs of cerebral palsy. In others the features may be related to sequelae of perinatal anoxia. As one would expect, there are all gradations in children, from the child who has unusual manual dexterity and unusually high ability at reading and writing to the clumsy child, the child who is late in acquiring some skills yet normal in others. It need hardly be added that some adults are clumsy in their movements and poor with their hands.

The importance of the problem is obvious. Failure to recognize that the symptoms are genuine and not due to naughtiness may lead to aggravation of the symptoms and so to a variety of behaviour problems, and it means in addition that the children cannot be given the specialized help and support which they need. Almost all teachers are sympathetic to a child who they know is handicapped; some are apt to be unkind to a child who they think is merely naughty.

It would seem that the school medical service and the family doctor have an important responsibility in this matter. Clumsy children are not at all uncommon. They should be referred to a paediatrician with interest and experience in the problem, who will enlist when necessary the help of an expert psychologist. The whole child must be studied. A detailed developmental and neurological examination is essential; hence the suggestion that the child should be referred in the first place to a paediatrician rather than to a psychologist or psychiatrist. When a child is backward it is essential to determine whether his backwardness is due simply to a low I.Q. or to other and remediable causes. When a child is backward in some things and yet normal in others it is all the more important to determine why he is backward. The worst thing we can do is to call him naughty when he has a physical handicap. There is a real need for a more concerted study of our backward children so that we can determine whether we can help them.

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(British Medical Journal, 1962)

The Authoritative Reference to Clumsy Children

DSM-IV Description of DCD
Motor Skills Disorder
315.4 Developmental Coordination Disorder
Diagnostic Features

The essential feature of Developmental Coordination Disorder is a marked impairment in the development of motor coordination (Criterion A). The diagnosis is made only if this impairment significantly interferes with academic achievement or activities of daily living (Criterion B). The diagnosis is made if the coordination difficulties are not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and the criteria are not met for Pervasive Developmental Disorder (Criterion C). If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it (Criterion D). The manifestations of this disorder vary with age and development. For example, younger children may display clumsiness and delays in achieving developmental motor milestones (e.g., walking, crawling, sitting, tying shoelaces, buttoning shirts, zipping pants). Older children may display difficulties with the motor aspects of assembling puzzles, building models, playing ball, and printing or handwriting.

Associated Features and Disorders

Problems commonly associated with Developmental Coordination Disorder include delays in other nonmotor milestones. Associated disorders may include Phonological Disorder, Expressive Language Disorder, and Mixed Receptive-Expressive Language Disorder.

Prevalence

Prevalence of Developmental Coordination Disorder has been estimated to be as high as 6% for children in the age range of 5-11 years.

Course

Recognition of Developmental Coordination Disorder usually occurs when the child first attempts such tasks as running, holding a knife and fork, buttoning clothes, or playing ball games. The course is variable. In some cases, lack of coordination continues through adolescence and adulthood.

Differential Diagnosis

Developmental Coordination Disorder must be distinguished from motor impairments that are due to a general medical condition. Problems in coordination may be associated with **specific neurological disorders** (e.g., cerebral palsy, progressive lesions of the cerebellum), but in these cases there is definite neural damage and abnormal findings on neurological examination. If **Mental Retardation** is present, Developmental Coordination Disorder can be diagnosed only if the motor difficulties are in excess of those usually associated with the Mental Retardation. A diagnosis of Developmental Coordination Disorder is not given if the criteria are met for a **Pervasive Developmental Disorder**. Individuals with **Attention-Deficit/ Hyperactivity Disorder** may fall, bump into things, or knock things over, but this is usually due to distractibility and impulsiveness, rather than to a motor impairment. If criteria for both disorders are met, both diagnoses can be given.

Diagnostic criteria for
315.4 Developmental Coordination Disorder

A. Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (e.g., walking, crawling, sitting), dropping things, "clumsiness," poor performance in sports, or poor handwriting.

B. The disturbance in Criterion A significantly interferes with academic achievement or activities of daily living.

C. The disturbance is not due to a general medical condition (e.g., cerebral palsy, hemiplegia, or muscular dystrophy) and does not meet criteria for a Pervasive Developmental Disorder.

D. If Mental Retardation is present, the motor difficulties are in excess of those usually associated with it.

Coding note: If a general medical (e.g., neurological) condition or sensory deficit is present, code the condition on Axis III.

(American Psychiatric Association 2000, pp. 57-58)

The Movement A.B.C.

From the Movement A.B.C. Handbook
By Henderson, S. and Sugden D.A. (1992)

The Movement ABC Test as a formal standardized assessment

Professionals assess children's performance for various reasons. Sometimes tests are used as part of the process of making judgments about children suspected of having special educational (or medical) needs. When there is some question of a child being different from others and failing to progress as expected, assessments are performed which lead to objective information on the extent of the problem and advice on how to proceed. For example, decisions about whether the child requires just a little additional help from the classroom teacher, or needs to be given assistance from a therapist or specialist teacher, are made at this stage.

At other times, tests are used to provide diagnostic information which may help teachers, therapists or parents to plan effective ways of helping a child. When used in this way, they must be seen within the more general context of data gathering and must provide information in a form that is applicable to program planning.

When considering the contribution of the Movement ABC Test to the process of assessment, the very formal administration which leads to reliable numerical scores has been consistently separated from the less formal assessment which, while not neglecting the numerical data, gives equal weight to the more qualitative information that the test yields. In this chapter, the data obtained from a formal assessment are dealt with. How to use the information from a less formal assessment is dealt with in Chapter 8.

The test scores and their interpretation

For decision-making purposes, the most important score from the Movement ABC Test is the Total Motor Impairment Score. This score summarizes performance on the test as a whole and is simply the sum of scores on the eight items that each child attempts during a formal assessment This Total Impairment Score is then interpreted in the light of the percentile norm tables given below.

Percentile norms have been chosen because they are readily understood and easily applied. Percentiles indicate the percentage of children who fall either above or below a particular raw score, depending on how a test is scored. Since on the Movement ABC high scores represent poor performance, a score which lies at the 2nd percentile will be higher than a score at the 10th percentile. Thus a child who scores 25 out of a possible 40 points on the Test is much less competent than the child who scores 12.

Tables 2 and 3 present norms for the Total Impairment Score in two levels of detail. Table 2 presents the data recommended for use in educational or clinical practice. Table 3 is recommended for research purposes and detailed measurement of change.

Since the eight-item scores that compose the Total Impairment Score were all scaled according to the same procedures at all ages, it was originally expected that the total score distributions would be so similar at all ages that a single norms table would adequately describe overall performance on the Movement ABC Test for all children. However, as the variability of Total Impairment Scores was found to be somewhat greater for ages 4 and 5 than for the older children and the difference was statistically significant, two sets of total score norms were prepared, one for children aged 4 or 5 years and one for children aged 6 through 12 years. These were then used to produce Tables 2 and 3.

Table 2 presents norms for the three percentile ranges used in previous editions of the test-at or below the 5th percentile, between the 5th and the 15th, and above the 15th percentile. These norms, divided into two sets for children aged 4 and 5 and those aged 6 upwards, provide sufficient precision for the Test's intended purposes, and are recommended for regular use.

Table 2. 5th and 15th percentile points for the Total Impairment Scores

	5th % ile	*15th % ile*
Age 4 and 5 years	17.0	10.5
Age 6 and above	13.5	10.0

As noted above, the cut-off points which represent the 5th and 15th percentile points for each age group are considered to be the ones which are most useful. Just as in the Movement ABC Checklist, Total Impairment Scores below the 5th percentile should be considered as indicative of a definite motor problem. In this case, additional help for the child is imperative, although the mode of provision might vary.

Scores between the 5th and 15th percentile suggest a degree of difficulty that is borderline. In this case, the decision to provide intervention will depend on the impact of the child's motor difficulty on the rest of his or her development and the resources available. In such cases, however, ongoing monitoring of the child's progress in the classroom using the Movement ABC Checklist is essential.

The movement competence of all other children is deemed to be adequate or better.

In Table 3 more detailed information on the total score distributions is provided. This shows the percentile norms for the age groups 4-5 and &-12+ years. In order to use the percentile norms found in this table, the examiner should look down the column of Total Impairment Scores until the child's total score or score interval is found and then read across the columns to find the percentile rank for that score. This table might be useful for researchers who want to make much more detailed differentiations between children in a study or for investigators involved in evaluation studies who want to measure change on a finer scale.

The words that are used to describe a child's motor status as inferred from performance on the Movement ABC should be chosen with care. Low scorers should not be labeled with diagnoses other than 'movement difficulties', 'motor impairment, 'motor delay' or 'developmental coordination disorder'. It should be noted that performance on the Test cannot be used to infer a diagnosis about a child's medical status. Additional, detailed, diagnostic information obtained from a pediatrician about the child would be required before any statement relating the Movement ABC Test performance to a physical disorder could be made. The examiner must also be sensitive to the possible harm that can come to a child who is labeled or mis-diagnosed. For example, the phrase 'minimal brain dysfunction' may imply to parents or professionals that nothing can be done for the child.

Table 3. Complete percentile norms for Total Impairment Scores by age in years

Total Impairment Score	% ile equivalents		Total Impairment Score	% ile equivalents	
	4-5	6-12+		4-5	6-12+
0	93	96	13	10	6
0.5	86	93	13.5	9	5
1	80	89	14	9	5
1.5	72	84	14.5	8	4
2	67	79	15	7	3
2.5	62	70	15.5	7	3
3	56	65	16	6	2
3.5	50	60	16.5	6	2
4	46	54	17	5	2
4.5	42	49	17.5	5	1
5	38	45	18	5	1
5.5	34	40	18.5	4	1
6	32	36	19	4	
6.5	29	32	19.5	4	
7	26	29	20	4	
7.5	24	26	20.5	3	
8	22	22	21	3	
8.5	21	20	21.5	3	
9	19	18	22	3	
9.5	18	16	22.5	2	
10	16	15	23	2	
10.5	15	13	23.5	1	
11	14	11	24	1	
11.5	13	9	24.5	1	
12	12	8	25+	1	
12.5	11	7			

Taking account of behavioural factors

Although the scores obtained on the Movement ABC Test are generally considered to be highly reliable and valid, there are times when it is useful to take some account of the way the child coped with the one-to-one testing situation. This should be done by consulting the behavioral observations completed at the end of the testing session. At this point, the crucial question to be asked is, 'Would the behavior or behaviors noted have prevented the child from demonstrating his or her true motor competence?' If the answer to this question is 'Yes', then the reasons for this conclusion must be discussed among the professionals involved in making decisions about how to proceed. A child who was excessively shy and uncooperative, for example, may need to be retested in another setting or on another occasion. A child who was so distractible that testing was difficult may need to be observed further in the classroom before a decision is reached.

Once a decision about intervention has been taken, of course, the significance of this information changes. The question that then needs to be asked is, 'How will this particular pattern of behavior affect the child's response to an intervention program and how might we plan in advance to ensure most progress?'

(Henderson & Sugden, 1992)

Shifting Pegs by Rows

9 and 10 years

Materials

Peg board
12 plastic pegs
Table-top mat
Stopwatch

Set-up

Place the peg board on the table-top mat. Place twelve pegs in the second, third, and fourth rows from the top, leaving the top row empty.

Task

The child holds the board steady with one hand and grasps the first peg to be moved with the other. The grasped peg must not be moved from its hole until the child is told to begin. At a signal the child moves the pegs in the second row to the first (top) row, those in the third to the second row, and those in the fourth row to the third. Stop timing when the child releases the last peg. Both hands are tested.

Demonstration

While demonstrating the task, emphasize:

- holding the board steady
- moving the pegs one at a time
- using only one hand during a single trial
- working as quickly as possible

Practice phase

Give the child one practice attempt with each hand. A practice attempt shall consist of the child moving one row of pegs. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials

TWO for each hand. Present the second trial only if needed to achieve the pass criterion. Test the preferred hand first, then the other. No assistance may be given during these trials.

Record

Number of seconds taken to complete each correct trial.
Failed trial (F) if the child commits a procedural fault, i.e.

- moves more than one peg at a time
- changes hands or uses two hands during a trial

(Henderson & Sugden, 1992)

Threading Nuts on Bolt

9 and 10 years

Materials

Bolt with fixed nut
3 loose nuts
Table-top mat
Stopwatch

Set-up

Place the bolt with the fixed nut on the mat with its head towards the child. Place the three loose nuts in a horizontal row at right angles to the bolt. Allow the child to choose the hand with which to pick up the bolt.

Task

The child holds the bolt in one hand and one of the nuts in the other. At a signal the nut is screwed down the bolt until it touches the fixed nut. The second and third nuts are then screwed on, one at a time, to meet the nuts already in position. Stop timing when the last of the three nuts is fully screwed on. All strategies that accomplish the task of putting the nuts on the bolt one at a time are acceptable.

Demonstration

While demonstrating the task, emphasize:

- screwing on one nut at a time
- holding the nut squarely to the bolt so that the thread engages
- working as quickly as possible

Practice phase

Give the child one practice attempt. A practice attempt shall consist of the child screwing one nut down the bolt until it touches the fixed nut. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials

TWO. Present the second trial only if needed to achieve the pass criterion. No assistance may be given during these trials.

Record

Number of seconds taken to screw on all three nuts correctly. Failed trial (F) if the child commits a procedural fault, i.e.

- screws on more than one nut at a time
- fails to screw the nuts on all the way to the fixed nut

(Henderson & Sugden, 1992)

Flower Trail

9 and 10 years

Materials

Flower trails (on Record Form)
Fine-tipped red pen Smooth writing base that is not too hard or slippery

Set-up

The child is seated at a table with both feet on the floor and arms resting comfortably on the table. The flower trail is placed in front of the child with the pen alongside.

Task

The child draws one continuous line, following the trail without crossing its boundaries. The child is not penalized for lifting the pen provided he or she starts drawing again at the same point. Allow the child to make small adjustments to the angle of the paper (up to 45 degrees) so it is easier to perform the task. Only the preferred hand is tested.

Demonstration

One of the trails from the Record Form can be used both in the demonstration and as the child's practice paper. While demonstrating the task, emphasize:

- keeping the pen in contact with the paper
- keeping between the boundary lines
- drawing as slowly as necessary to keep within the boundaries
- drawing the line in only one direction, especially over the points of the flower

Practice phase

Give the child one practice attempt. As this is a time-consuming task, only part of a trail need be practiced. If the examiner does half of a trail in the demonstration, the child could be given the rest as practice. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials

TWO. Present the second trial only if needed to achieve the pass criterion. No assistance may be given during these trials.

Record

Hand used to perform the task.
Number of errors, i.e. the number of times the drawn line moves outside one of the boundaries. It is not an error to run on a boundary. Count an additional error for each half-inch (12 mm) that the line continues outside the boundary.
Failed trial (F) if the child commits a procedural fault, i.e.

- reverses direction while drawing (this happens most often as the child moves the pen through the points of the flower)
- picks up the pen and starts drawing the line again somewhere else

(Henderson & Sugden, 1992)

Two hand Catch

9 and 10 years

Materials

Tennis ball
Colored tape

Set-up

Measure a distance of 6 feet (2 m) from a smooth wall and mark it with a short strip of tape.

Task

The child throws the ball at the wall from behind the marked distance and catches it on the return with both hands.

Demonstration

While demonstrating the task, emphasize:

- staying behind the line while throwing the ball
- stepping over the line or to one side, when necessary, to catch the ball
- throwing the ball hard enough to give a good rebound
- catching the ball before it bounces on the floor
- catching the ball with the hands rather than trapping it against the body or clothing

Practice phase

Give the child five practice attempts. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate. The child is not penalized for using two hands to throw the ball, but if the examiner thinks the child would be better to use one hand for throwing then she or he should be encouraged to do so. The examiner should not stress the transition between the practice phase and formal trials.

Formal trials

TEN attempts. No assistance may be given during these trials. If, however, the child fails an attempt, the examiner must remind the child of the fault (s) before proceeding to the next trial.

Record

Number of correctly executed catches out of 10 attempts. A trial is failed if the child commits a procedural fault, i.e.

- steps over the line to throw the ball
- catches the ball by trapping it against the body or clothing

(Henderson & Sugden, 1992)

Throwing Bean Bag into Box

9 and 10 years

Materials

Bean bag
Target box
Colored tape

Set-up

Place the target box on the floor with the short side facing the child. Measure a distance of 8 feet (2.5 m) from the front of the target box and mark with a short piece of tape.

Task

The child throws the bean bag into the target box with one hand. Only one hand is tested.

Demonstration

While demonstrating the task, emphasize:

- remaining behind the line while throwing
- standing in the position most comfortable for throwing the bag
- throwing the bag with only one hand

Practice phase

Give the child five practice attempts. During these trials the child may change hands if he or she wishes, but must choose one only for the formal tests. The child is not penalized for throwing the bag overhand but it should be discouraged. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate. The examiner should not stress the transition between the practice phase and formal trials.

Formal trials

TEN attempts. No assistance may be given during these trials.

Record

Hand used to perform the task.
Number of successfully executed throws out of 10 attempts.
A trial is failed if the child commits a procedural fault, i.e.

- steps over the line while throwing the bag

(Henderson & Sugden, 1992)

One-board Balance

9 and 10 years

Materials

Stopwatch
Balance board (jumping stand base)
Child must wear gym shoes or trainers

Set-up

The child should be tested in a clear space, away from walls and furniture. The examiner is responsible for providing a non-skid surface on which to place the balance board. Place the balance board on the non-skid surface with the narrow strip (keel) on the ground. The examiner should assume a position which allows a clear view of the feet. The examiner must be able to see whether or not the sides of the board touch the floor while the child is performing the task.

Task

The child balances on one foot, on a balance board, for up to 20 seconds. Once the child has achieved the balance position, start timing. Both legs are tested.

Demonstration

While demonstrating the task, emphasize:

- placing the foot on the middle of the board, directly over the keel
- keeping the board from tilting so the sides do not touch the floor
- keeping the free foot off the floor, away from the other leg and the balance board
- using the arms to balance if necessary

Practice phase

Give the child one practice attempt with each leg for a maximum of 10 seconds. The examiner may help the child assume the balance position. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials

TWO for each leg. Present the second trial only if needed to achieve the pass criterion.

Record

Number of seconds (up to 20) the child maintains balance without committing a procedural fault, i.e.

- tilting the board so that a side touches the floor
- touching the floor with the free foot

(Henderson & Sugden, 1992)

Hopping in Squares
9 and 10 years

Materials
Colored tape

Set-up
Tape down six adjacent squares, each with an inside measurement of 18 x 18 inches (0.45 m), to give an overall length of 9 feet (2.7 m).

Task
The child starts the task standing on one foot inside the first square. The child makes five continuous hops forward from square to square, stopping inside the last square. The last hop does not count if the child fails to finish in a balanced, controlled position, or makes an extra hop outside the square. Both legs are tested.

Demonstration
While demonstrating the task, emphasize:
- hopping inside the squares
- hopping once inside each square
- keeping the free foot from touching the ground
- finishing the series of hops in a balanced, controlled position inside the last square-this is achieved by bending the knee to accommodate the hop, and controlling momentum.

Practice phase
Give the child one practice attempt with each leg. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials
THREE for each leg. Present the second and third trials only if needed to achieve the pass criterion. No assistance may be given during these trials.

Record
Number of correct consecutive hops (maximum of 5) completed without committing a procedural fault, i.e.
- hopping on or outside the lines
- hopping more than once in a square
- letting the free foot touch the floor

(Henderson & Sugden, 1992)

Ball Balance
9 and 10 years

Materials
2 jumping stands
Tennis ball
Pegboard

Set-up
Place the jumping stands on the floor with a gap of 9 feet (2.7 m) between them.

Task
Place the peg board and ball on a table so the child may pick them up with either hand. The child takes up a position halfway between the two jumping stands. The child lays the peg board (holes down) on the palm of one hand and places the ball in the middle of it. The child must steady the board so that the ball remains stationary without being held. No part of the hand should be above the upper surface of the board. The child then walks around the outside of the jumping stands and returns to the starting point. If the ball is dropped, the examiner picks it up and returns it to the child, who replaces it on the board. Once it is steady again, the child continues walking from the point at which the ball fell. Only one hand is tested.

Demonstration
While demonstrating the task, emphasize:
- balancing the board on the palm of the hand
- walking as slowly as necessary to keep the ball balanced
- replacing the ball and continuing to walk from that point if the ball is dropped

Practice phase
Give the child one practice attempt. If any fault of procedure is observed the examiner should interrupt at the earliest opportunity and give a reminder or re-demonstrate.

Formal trials
TWO. Present the second trial only if needed to achieve the pass criterion. No assistance may be given during these trials, other than returning a dropped ball to the child.

Record
Hand used to hold the board.
Number of times the ball drops off the board, up to 10 times. Failed Trial (F) if the child commits a procedural fault i.e.
- holds the board improperly, for example, with the thumb on the upper surface
- drops the ball and does not resume walking from the point of the drop
- uses the free hand to catch or steady the ball while walking

(Henderson & Sugden, 1992)

RECORD FORM

MOVEMENT ABC

Movement Assessment Battery for Children

Compiled by Sheila E. Henderson and David A. Sugden

AGE BAND 3 — 9–10 years

Name .... Gender ....

Home address .... Date of test ....

.... Date of birth ....

.... Age ....

School .... Grade/class ....

....

Assessed by ....

Preferred hand (defined as the hand used to write with) ....

Other information ....

....

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INFLUENCES ON PERFORMANCE

Complete the sections below by noting any physical factors or features of the child's behavior during testing which you suspect might have affected his or her motor performance. Headings (with examples) are given as guidelines only. Although negative aspects are given more emphasis, remember to note positive aspects of the child's behavior.

BEHAVIORAL FACTORS

- **Overactive** (squirms and fidgets; moves constantly when listening to instructions; fiddles with clothes) ....
- **Passive** (hard to interest; requires much encouragement to participate; seems to make little effort) ....
- **Timid** (fearful of activities like jumping and climbing; does not want to move fast; constantly asks for assistance) ....
- **Tense** (appears nervous, trembles; fumbles with small objects; becomes flustered in a stressful situation) ....
- **Impulsive** (starts before instructions/demonstrations are complete; impatient of detail) ....
- **Distractible** (looks around; responds to noises/movement outside the room) ....
- **Disorganized/confused** (has difficulty in planning a sequence of movements; forgets what to do next in the middle of a sequence) ....
- **Overestimates own ability** (tries to change tasks to make them more difficult; tries to do things too fast) ....
- **Underestimates own ability** (says tasks are too difficult; makes excuses for not doing well before beginning) ....
- **Lacks persistence** (gives up quickly; is easily frustrated; daydreams) ....
- **Upset by failure** (looks tearful; refuses to try task again) ....
- **Appears to get no pleasure from success** (makes no response to feedback; has a blank facial expression) ....
- **Other** ....

PHYSICAL FACTORS

- Weight/height/weight in relation to height ....
- Vision/hearing/speech ....
- Anatomical/postural defect ....
- Other ....

SUMMARY OF QUANTITATIVE DATA

MOVEMENT ABC CHECKLIST SCORE Motor score

_____ + _____ + _____ + _____ = _____

MOVEMENT ABC TEST SCORE

Manual Dexterity _____ + _____ + _____ = _____

Ball Skills _____ + _____ = _____

Static and Dynamic Balance _____ + _____ + _____ = _____

TOTAL IMPAIRMENT SCORE $\boxed{}$

SUMMARY OF QUALITATIVE OBSERVATIONS

MANUAL DEXTERITY (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

BALL SKILLS (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

STATIC AND DYNAMIC BALANCE (Body control/posture; functioning of limbs; spatial accuracy, control of force/effort, timing of actions; other observations including response to feedback during *informal* testing)

SHIFTING PEGS BY ROWS — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Preferred hand	Nonpreferred hand
Trial 1	Trial 1 ....
Trial 2	Trial 2 ....

age 9	age 10	score	age 9	age 10
0–12	0–12	0 / 0	0–14	0–13
13	13	1 / 1	15	14
14	–	2 / 2	16	15
15	14	3 / 3	17	16
16–17	15–16	4 / 4	18–19	17
18+	17+	5 / 5	20+	18+

Item score*

* Item score = (Preferred hand + Nonpreferred hand) ÷ 2

Qualitative observations

Body control/posture

- Does not look at board while inserting pegs ☐
- Holds face too close to task ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to pick up pegs ☐
- Exaggerates finger movements in releasing pegs ☐
- Does not use the supporting hand to hold board steady ☐
- Does *extremely* poorly with one hand (asymmetry striking) ☐
- Changes hands or uses both hands during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Misaligns pegs with respect to holes ☐
- Uses excessive force when inserting pegs ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐

Other

....

....

THREADING NUTS ON BOLT — MANUAL DEXTERITY

Quantitative data

Record **time taken** (secs); **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....

score	age 9	age 10
0	0–20	0–17
1	21–23	18–19
2	24	20–21
3	25–28	22
4	29–33	23–24
5	34+	25+

Item score

Qualitative observations

Body control/posture

- Does not look at nuts and bolt while threading ☐
- Holds materials too close to face ☐
- Holds head at an odd angle ☐

- Does not use pincer grip to pick up nuts ☐
- Does not hold the bolt steady to receive nuts ☐
- Finds it difficult to coordinate hand movements ☐
- Changes threading hand during a trial ☐
- Hand movements are jerky ☐

- Sitting posture is poor ☐
- Moves constantly/ fidgets ☐

Adjustments to task requirements

- Does not align the nuts correctly on bolt ☐
- Tries to force nut when misaligned ☐
- Is *exceptionally* slow/does not change speed from trial to trial ☐
- Goes too fast for accuracy ☐

Other

....

....

FLOWER TRAIL — MANUAL DEXTERITY

Quantitative data

Record **number of deviations**; **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1 ....
Trial 2 ....
Hand used ....

score	age 9	age 10
0	0	0
1	1	1
2	–	–
3	2	2
4	3	–
5	4+	3+

Item score

Qualitative observations

Body control/posture

- Does not look at trail ☐
- Holds face too near paper ☐
- Holds head at an odd angle ☐

- Holds pen with an odd/immature grip ☐
- Holds pen too far from point ☐
- Holds pen too close to point ☐
- Does not hold paper still ☐
- Changes hands during a trial ☐

- Sitting posture is poor ☐
- Moves constantly/fidgets ☐

Adjustments to task requirements

- Progresses in short jerky movements ☐
- Uses excessive force, presses very hard on paper ☐
- Is *exceptionally* slow ☐
- Goes too fast for accuracy ☐

Other

....

....

TWO-HAND CATCH — BALL SKILLS

Quantitative data

Record **number of correct catches**; **R** for refusal;
I for inappropriate

....

score	age 9	age 10
0	6–10	8–10
1	5	7
2	4	6
3	3	4–5
4	1–2	1–3
5	0	0

Item score

Qualitative observations

Body control/posture

- Does not follow trajectory of ball with eyes ☐
- Turns away or closes eyes as ball approaches ☐

- Arms are not raised symmetrically for catching ☐
- Holds hands out flat with fingers stiff as the ball approaches ☐
- Arms and hands do not 'give' to meet impact of ball ☐
- Fingers close too early or too late ☐

- Body appears rigid/tense throughout ☐

Adjustments to task requirements

- Does not adjust body position for catching ☐
- Does not adjust position of feet as necessary ☐
- Judges force of throw poorly (too much or too little) ☐
- Movements lack fluency ☐

Other

....

....

THROWING BEAN BAG INTO BOX — BALL SKILLS

Quantitative data

Record **number of goals**; **R** for refusal; **I** for inappropriate

....
Hand used ....

score	age 9	age 10
0	5–10	6–10
1	4	5
2	3	–
3	2	4
4	–	3
5	0–1	0–2

Item score

Qualitative observations

Body control/posture

- Does not keep eyes on target ☐
- Does not use a pendular swing of the arm ☐
- Does not follow through with throwing arm ☐
- Releases bean bag too early or too late ☐
- Changes hands from trial to trial ☐
- Trunk and hips do not rotate as throwing arm comes forward ☐
- Over-rotates and loses balance ☐

Adjustments to task requirements

- Errors are consistently to one side of the box (asymmetry striking) ☐
- Judges force of throw poorly (too much or too little) ☐
- Control of force is variable ☐
- Movements lack fluency ☐

Other

....

....

ONE-BOARD BALANCE — STATIC BALANCE

Quantitative data

Record **time balanced** (secs); **R** for refusal; **I** for inappropriate

Preferred leg	Nonpreferred leg
Trial 1	Trial 1 ....
Trial 2	Trial 2 ....

age 9	age 10	score	age 9	age 10
6–20	9–20	0 / 0	6–20	8–20
5	6–8	1 / 1	5	6–7
4	5	2 / 2	4	5
3	4	3 / 3	3	4
2	3	4 / 4	2	3
0–1	0–2	5 / 5	0–1	0–2

* Item score

* Item score = (Preferred leg + Nonpreferred leg) ÷ 2

Qualitative observations

Body control/posture

- Does not hold head and eyes steady ☐
- Looks down at feet ☐
- Makes no or few compensatory arm movements to help maintain balance ☐
- Exaggerated movements of arms and trunk disrupt balance ☐
- Body is held rigid ☐
- Sways wildly to try to maintain balance ☐
- Does *extremely* poorly on one leg (asymmetry striking) ☐

Other

....

....

HOPPING IN SQUARES — DYNAMIC BALANCE

Quantitative data

Record **number of correct hops**; **F** for failure; **R** for refusal; **I** for inappropriate.

Preferred leg	Nonpreferred leg
Trial 1	Trial 1 ....
Trial 2	Trial 2 ....
Trial 3	Trial 3 ....

age 9	age 10	score	age 9	age 10
5	5	0/0	5	5
–	–	1/1	–	–
–	–	2/2	4	4
4	4	3/3	3	3
1–3	3	4/4	1–2	2
0	0–2	5/5	0	0–1

* Item score

* Item score = (Preferred leg + Nonpreferred leg) ÷ 2

Qualitative observations

Body control/posture

- Does not use arms to assist hop ☐
- Arms swing out of phase with legs ☐
- Arm movements are exaggerated ☐

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐

- Nonsupporting leg held up in front of body ☐
- Lacks springiness/no push-off from feet ☐
- Noticeably poorer on one foot than the other ☐
- Hops with stiff legs/on flat feet ☐
- Stumbles on landing ☐

Adjustments to task requirements

- Does not combine upward and forward movements effectively ☐
- Uses too much effort ☐
- Movements are jerky ☐

Other

....

....

BALL BALANCE — DYNAMIC BALANCE

Quantitative data

Record **number of drops**; **F** for failure; **R** for refusal; **I** for inappropriate

Trial 1	Hand used ....
Trial 2	
Trial 3	

score	age 9	age 10
0	0	0
1	–	–
2	1	1
3	2	2
4	3–4	3–4
5	5+	5+

Item score

Qualitative observations

Body control/posture

- Does not look ahead ☐
- Does not keep head steady ☐

- Does not compensate with free arm to maintain balance ☐
- Exaggerated arm movements disrupt balance ☐

- Body appears rigid/tense ☐
- Body appears limp/floppy ☐
- Shuffles forward, does not lift feet off floor ☐

Adjustments to task requirements

- Goes too fast to control ball ☐
- Individual movements lack smoothness and fluency ☐
- Sequencing of steps is not smooth/pauses frequently ☐

Other

....

....

2 3 4 5 6 7 8 9 0 1
A B C D E F G H I J

REVIEW: MOVEMENT ASSESSMENT BATTERY FOR CHILDREN CHECKLIST

The MABC (Henderson & Sugden, 1992) consists of two independent instruments: the MABC Test and the MABC Checklist. The MABC Test is an ability-oriented instrument that I described and critiqued in chapter 8. The focus of the present discussion is the MABC Checklist, which is based on the variety of checklists used by Keogh and his students at the University of California, Los Angeles, to help physical education teachers identify children with movement difficulties (e.g., Keogh, Sugden, Reynard, & Calkins, 1979). The MABC Checklist is a direct derivative of the more recent Motor Competence Checklist reported by Sugden and Sugden (1991).

Some of the information in the qualitative checklists that were included in the Henderson Revision of the Test of Motor Impairment (Stott, Moyes, & Henderson, 1984) is also incorporated into the MABC Checklist.

The two instruments included in the MABC-the Test and the Checklist-are designed to complement each other in the movement assessment process for children 4 to 12 years of age. For screening children, identifying children for special services, and conducting research, either the Test or the Checklist may be used. For clinical exploration, intervention planning, and program evaluation, it is recommended that both the Test and Checklist be used.

Usage of previous versions of the MABC Checklist (e.g., Keogh et al., 1979; Sugden & Sugden, 1991) was quite limited, while the current version has been available only for a short time and thus has not yet had a chance to become established as an assessment option for professionals interested in evaluating children with movement difficulties.

Structure

The MABC Checklist allows teachers, other professionals, or even parents to evaluate a child's movement behaviors in a variety of natural settings over an extended period of time. The Checklist, designed specifically for children between 5 and 11 years of age, contains tasks often encountered in a school environment. The focus on movement in natural settings justifies the classification of the Checklist as a functional movement skill assessment instrument.

The Checklist is divided into five sections, with 12 items in each section. The first four sections, derived from Gentile's (1987) 16-category taxonomy of movement skills (see table 3.3), are labeled as (a) child stationary-environment stable, (b) child moving-environment stable, (c) child stationary-environment changing, and (d) child moving-environment changing. The last section lists behaviors that may interfere with a child's movement performance. Examples of the five sets of tasks are presented in figure 11.5.

The 48 items in the four motor sections are scored on a four-level, ordinal scale: 0 = very well, 1 = just OK, 2 = almost, and 3 = not close. The higher scores for poorer performances reflect the emphasis of this test on motor impairment. The results may be interpreted at three levels. First, the total score may be matched against sums corresponding to the 5th ("movement problems") and 15th ("at risk") percentiles for 6-,7-,8-, and 9+-year-olds . Next, the subtotals for each of the four sections may be compared to identify categories of movement tasks that may pose special problems for a child. And third, individual items may be examined for information on the specific tasks that are especially challenging for a child.

Section 1. Child stationary - environment stable

1. The child can put on and take off articles of clothing without assistance (shirt, sweater, socks).

8. The child can form letters, numbers, and basic geometric shapes that are accurate and legible.

Section 2. Child moving - environment stable

2. The child can carry objects around the classroom/school avoiding a collision with stationary objects/persons.

9. The child can throw an object (ball, beanbag, ring) into a container using an underarm action, while on the move.

Section 3. Child stationary - environment changing

3. The child can intercept and stop a moving object (toy train or car, ball) as it approaches/ enters the field of reach.

10. The child can continually bounce a large playground ball while standing still.

Section 4. Child moving - environment changing

4. The child can push/pull wheeled vehicles such as wagons, library and mat trolleys.

11. The child can move to enter a turning jump rope.

Section 5. Behavioral problems relating to motor difficulties

5. The child is impulsive (starts before instructions/ demonstrations are complete; impatience of detail).

12. The child is apparently unable to get pleasure from success (makes no response to feedback; has a blank facial expression).

FIGURE 11.5 Sample of items from each of the five sections in the MABC Checklist (from Henderson & Sugden, 1992).
Reproduced with permission by The Psychological Corporation LTD © The Psychologoical Corporation LTD 1992, Foots Cray High Street, Sidcup, Kent DA14 5HP, United Kingdom.

The 12 behavior items are scored as a (rarely), 1 (occasionally), or 2 (often), but are not summed. Instead, the rater classifies the overall contribution of these behaviors to movement difficulties as high, medium, or low. The rater must consider not only whether the behaviors limit a child's movement performance, but also whether they should be taken into account in developing an intervention program.

Reliability

To examine the test-retest reliability of the MABC Checklist, Henderson and Sugden (1992) asked 41 teachers to complete the Checklist on one child in their classroom two times across a span of 1 month. The Pearson product-moment correlation between the two testings for the total motor score (the first four sections) was .89, while the correlations for the individual sections were .88, .84, .77, and .76, respectively. Although interclass correlations may not be the best way to evaluate test-retest reliability, these values still are quite high given the subjective nature of the Checklist. Information on the reliability of a developmental version of the MABC Checklist referred to as the Motor Competence Checklist, is described in a paper b; Sugden and Sugden (1991).

Validity

The validity of the MABC Checklist was investigated in a study of 6- to 9-year-old children in the United Kingdom (Henderson & Sugden, 1992; see also Sugden & Sugden, 1991). Three boys and three girls were randomly selected from 50 different classes (n = 298), as well as the one boy and one girl whom the teachers judged as having the most difficulty with their movement skills (n = 47). As expected, scores for the children in the random sample significantly decreased with age; however, the girls' scores were significantly lower than the boys', a result for which an adequate explanation was not given. Also as expected, the scores for Sections 3 and 4 (changing environment) were significantly higher than the scores for Sections 1 and 2 (stable environment), indicating that the Checklist is sensitive to environment demands.

The children identified as having the most difficulty with their movement skills scored significantly higher than the other children on the MABC Checklist, indicating an agreement between the teachers' judgments and the results of the Checklist. Only 72% of the children whom the teachers judged as having the most difficulty with their movement skills scored below the 15th percentile, but it was not determined whether other children who were not selected would have scored lower.

Next, the authors examined the agreement between the MABC Checklist and the MABC Test by comparing the Test scores of the 16 children in the random sample who scored lowest on the Checklist (all below the 5th percentile) with the scores of 16 children who scored above the 15th percentile. Contrary to expectations, 9 of the 16 who scored lowest on the Checklist scored above the 15th percentile on the Test. Henderson and Sugden (1992) explained that the MABC Checklist will always identify more children as having difficulty than the MABC Test because the contexts in which the movement skills are evaluated are much broader. Accordingly, the children with better scores on the Checklist also had significantly lower scores on the Test; but, contradicting the authors' argument, 2 of the 16 (12.5%) scored below the 15th percentile on the Test

Finally, the summed score in Section 5 of the Checklist (behavioral problems related to motor difficulties) was analyzed in relation to a child's age, sex, and summed score in the four motor sections, even though the summing of scores from the items in Section 5 is not part of the standard Checklist protocol. The Section 5 scores for the group of randomly selected children significantly decreased with increasing age and were significantly lower for girls, matching the patterns for total scores in the four motor sections. Moreover, the correlation between scores in Section 5 and total ores across Sections 1 through 4 was .67, prompting Henderson and Sugden (1992) to conclude that "many children with movement difficulties are hindered by associated behavior problems and that these are evident to the teacher who observes them" (p. 217).

Some further study on the validity of the MABC Checklist has been carried out with children from Singapore. Wright, Sugden, Ng, and Tan (1994) assessed 212 children, 7 and 8 years old, with the MABC Checklist and found that 10.9% fit into the at risk category, between the 5th percentile and 15th percentile, and 4.7% fit into the movement problems category, between the 0 percentile and 5th percentile. These percentages very closely match the expected values of 10% and 5%, respectively. All children at or low the 15th percentile were considered to have a developmental coordination disorder (DCD). In a follow-up study, Wright and Sugden (1996) found similar percentages with a group of 427 Singaporean children ranging in age from 6 to 9 years: 10.1 % in the at risk category and 6.1 % in the movement problems category. Further, Wright and Sugden (1996) reported that scores from just Section 4 (child moving-environment changing) could be used to correctly classify 81 % of the children with DCD; this result, they argued, suggests that these children differed most from their well-coordinated peers when they were required to move in a dynamic environment.

Wright and Sugden (1996) also examined the subtypes of DCD by running a factor analysis on the results for the DCD children only on the first four 'ons of the MABC Checklist and the eight areas on the MABC Test. They found that Sections 1 and 2 of the MABC Checklist formed one cluster while 'ons 2, 3, and 4 formed another, indicating that the distinction between stationary and changing environments is more important than the distinction between a stationary and moving performer and that the MABC Checklist tapping different movement skill qualities than the MABC Test.

Summary

Henderson and Sugden (1992) state that the MABC Checklist may be used (a) screening or identifying children for special services and (b) clinical exploration, intervention planning, and program evaluation. I will discuss the usefulness of the MABC Checklist for these two sets of purposes separately.

First, the children who were chosen by teachers as having difficulty with their movement skills did score significantly higher on the Checklist the other children, but this is not adequate evidence to validate the Ch list for screening or placement purposes. As with the Test, comparisons need to be made in terms of dichotomous categories congruent with Checklist, not absolute scores. On examination of the agreement between the Checklist and the Test in dichotomous terms, the Checklist was found to have a much higher identification rate, with more than 50% of those who scored at or below the 15th percentile on the Checklist scoring a the 15th percentile on the Test. Also, 12.5% of the children who scored above the 15th percentile on the Checklist scored at or below the 15th percentile on the Test, placing the sensitivity of the Checklist into question. In addition, the reliability of these categorical decisions needs to be established for the Checklist.

Henderson and Sugden (1992) presented no empirical evidence that either the MABC Test or Checklist is valid for clinical exploration or intervention planning. However, the sampling of movement performance many contexts in the Checklist, as well as related behaviors in Section 5 appears to be very useful for clinical exploration and intervention planning, regardless of the total scores. The manual presented one extensive case study showing how the Test and Checklist can be used to develop intervention plan. Similar but less detailed case studies would be helpful in establishing the validity of the Checklist for clinical exploration and intervention. The case studies also should include an evaluation of progress using both the Test and the Checklist, as well as other independent sources.

In conclusion, we have insufficient evidence that the MABC Checklist is a reliable and valid instrument. It does, however, have several unique features-in particular, a JBA format focusing on movement behaviors in natural settings-that appear to have potential usefulness for screening, intervention planning, and clinical exploration.

(Burton and Miller 1998, p276 -282)

STRENGTH AND MUSCULAR ENDURANCE ASSESSMENT

Measures of static or dynamic strength and endurance are used to establish baseline values before training, monitor progress during training, and assess the overall effectiveness of resistance training and exercise rehabilitation programs. Static strength and muscular endurance are measured using dynamometers, cable tensiometers, and load cells. Free weights (barbells and dumbbells), as well as constant-resistance, variable-resistance, and isokinetic exercise machines, are used to assess dynamic strength and endurance (see table 6.1.). The testing procedures vary depending on the type of test (i.e., strength or endurance) and equipment.

Isometric Muscle Testing Using Dynamometers

You can use isometric dynamometers to measure static strength and endurance of the grip squeezing muscles and leg and back muscles (see figure 6.3). The handgrip dynamometer has an adjustable handle to fit the size of the hand and measures forces between 0 and 100 kilograms (kg), in 1-kg increments. The back and leg dynamometer consists of a scale that measures forces ranging from 0 to 2500 lb in 10-lb increments. Both dynamometers are spring devices. As force is applied to the dynamometer, the spring is compressed and moves the indicator needle a corresponding amount.

TABLE 6.1 Strength Testing Modes

Testing Mode	Equipment	Measure
Static	Isometric dynamometers, cable tensiometers, and load cells	MVC (kg)
Dynamic Constant-resistance Variable-resistance	Free weights (barbells and dumbbells) and exercise machines Exercise machines	1-RM (lb or kg) NA
Isokinetic and omnikinetic	Isokinetic and omnikinetic dynamometers	Peak torque (Nm or ft-lb)

MVC = maximum voluntary contraction
NA= not applicable
Nm = Newton meter
Ft lb + foot pound

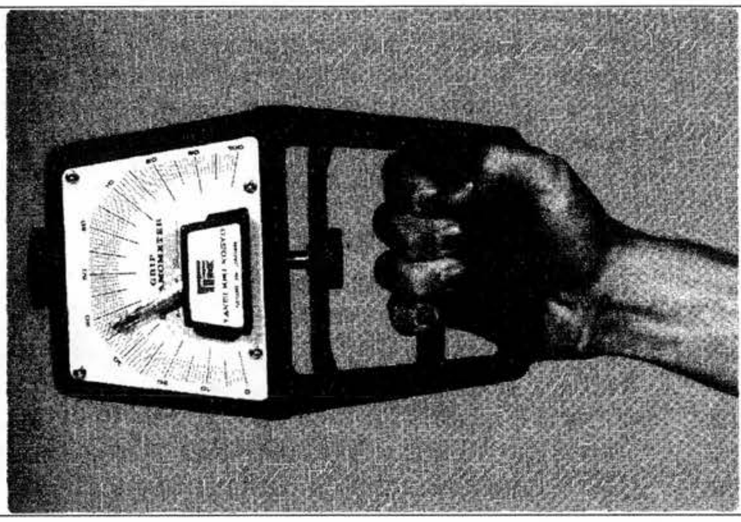
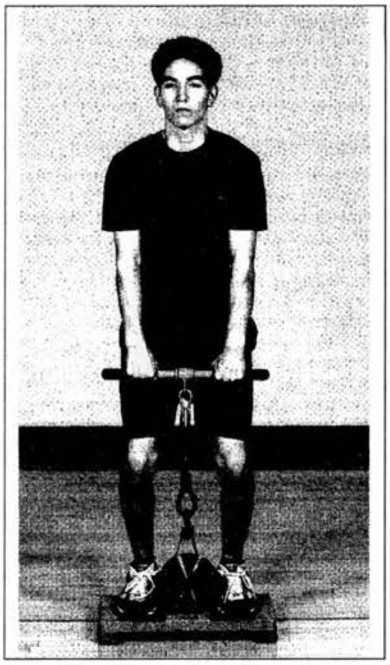


Figure 6.3 Dynamometers for measuring static strength and endurance: (a) handgrip dynamometer and (b) back and leg dynamometer.

Grip Strength Testing Procedures

Before using the handgrip dynamometer, adjust the handgrip size to a position that is comfortable for the individual. Alternatively, you can measure the hand width with a caliper and use this value to set the optimum grip size (Montoye and Faulkner 1964). The individual stands erect, with the arm and forearm positioned as follows (Fess 1992): shoulder adducted and neutrally rotated, elbow flexed at 90°, forearm in the neutral position, and wrist in slight extension (0° to 30°). For some test protocols, however, the client must keep the arm straight and slightly abducted when measuring the grip strength of each hand (Canadian Society for Exercise Physiology 2003). The individual squeezes the dynamometer as hard as possible using one brief maximal contraction and no extraneous body movement. Administer three trials for each hand, allowing a 1-min rest between trials, and use the best score as the client's static strength.

Leg Strength Testing Procedures



Using the back and leg dynamometer, the individual stands on the platform with trunk erect and the knees flexed to an angle of 130^0 to 140^0• The client holds the hand bar using a pronated grip and positions it across the thighs by adjusting the length of the chain (see figure 6.3b). If a belt is available, attach it to each end of the hand bar after positioning the belt around the client's hips. The belt helps to stabilize the bar and to reduce the stress placed on the hands during the leg lift. Without using the back, the client slowly exerts as much force as possible while extending the knees. The maximum indicator needle remains at the peak force achieved. Administer two or three trials with a 1-min rest interval. Divide the maximum score (in pounds) by 2.2 to convert it to kilograms.

Back Strength Testing Procedures

Using the back and leg dynamometer, the individual stands on the platform with the knees fully extended and the head and trunk erect. The client grasps the hand bar using a pronated grip with the right hand and a supinated grip with the left. Position the hand bar across the client's thighs. Without leaning backward, the client pulls the hand bar straight upward using the back muscles and is instructed to roll the shoulders backward during the pull. Clients should be reminded before lifting to flex the trunk minimally and to keep the head and trunk erect during the test. Administer two trials with a 1-min rest between the trials. Divide the maximum score (in pounds) by 2.2 to convert it to kilograms.

Static Strength Norms

Table 6.2 provides age-gender norms for evaluating the static grip strength of the right and left hands combined. Grip strength norms for each hand are presented in table 6.3. You can also use norms developed for men and women to assess your client's static strength for each dynamometric test item (see table 6.3). Calculate your client's total strength score by adding the right grip, left grip, leg strength, and back strength scores. Before doing this, convert the leg and back strength scores (measured in pounds) to kilograms. To calculate the relative strength score, divide the total strength score by body mass (expressed in kilograms).

TABLE 6.2 Age-Gender Norms for Combined Isometric Grip Strength

GRIP STRENGTH (KG)*								
	15-19YR		20-29YR		30-39YR		40-49YR	
Rating	M	F	M	F	M	F	M	F
Excellent	2:108	2:68	2:115	2:70	2:115	2:71	2:108	2:69
Very good	98-107	60-67	104-114	63-69	104-114	63-70	97-107	61-68
Good	90-97	53-59	95-103	58-62	95-103	58-62	88-96	54-60
Fair	79-89	48-52	84-94	52-59	84-94	51-57	80-87	49-53
Needs improvement	<78	<47	<83	<51	<83	<50	<79	<48

'Combined right- and left-hand grip strength scores.
M = males; F = females.
Source: The Canadian Physical Activity. Fitness and Lifestyle Approach: CSEP-Health & Fitness Program's Health-Related Appraisal and Counselling Strategy, 3" Edition © 2003. Adapted with permission of the Canadian Society for Exercise Physiology.

(Heyward 2006, p118 - 120)

The Intervention

Extracts from

elevating
athletics

www.elevatingathletics.com

NASUWT

uk:athletics

Health and Safety

There are certain fundamental precautions that need to be taken to ensure that the learning and teaching of athletics is safe and fun for all. This section aims to outline these but is by no means definitive. It is assumed that teachers will take full responsibility for making their athletics lessons as safe as possible. If you require any further information please refer to the British Association of Advisers and Lecturers in Physical Education at **www.baalpe.org**
A risk assessment must be conducted out before carrying out any athletic activities.

Environment and Surfaces

Start by ensuring that the environment your students are to learn athletics in is suitable. Safety is greatly enhanced by a safe working space.

- The activity surface should be in a good condition and level.
- During inclement weather, surfaces should be checked for suitability. Rain, snow and frost can render surfaces hazardous.
- The surface of the hall or gymnasium should be in good condition, clean and dry.

Equipment

- Damaged equipment should never be used.
- Equipment should be clean.
- Equipment should be safely stored when not being used.
- Pupils should be encouraged to get involved with safety checks to promote good health and safety practice.
- Any equipment that is considered to be unsafe should be labelled and removed from the area.
- If equipment is to be used for a purpose for which it was not primarily designed great care should be taken.

Clothing and footwear

- Parents should always be informed of the correct mode of dress required for athletics lessons and on which days these lessons will occur. It is with their cooperation that the safest attire will be achievable for all students.

Clothing should not be so loose that it obstructs movement, nor should it be so tight that it restricts movement.

- Spectacles should have plastic or unbreakable lenses.
- It may be necessary for students to wear tracksuit bottoms and / or long sleeves when using sandpits to prevent friction burns.
- All jewellery and watches should be removed prior to the lesson commencing.
- Items of jewellery that cannot be removed should be covered with surgical tape.
- In the event that a student wishes to wear different clothing in accordance with their religious of cultural traditions, this should be discussed and a suitable outcome agreed on, resulting in maintaining respect for the individual's beliefs at the same time as enabling safe participation.
- Footwear should provide good support and appropriate cushioning for the activity being carried out.
- Laces should be well tied and there should be no obstruction such as loose tongues of shoes.

Organisation

- Activities should be so arranged so that the area is large enough for students to have sufficient space to complete the activity and the likelihood of any collision is avoided.
- Activities should be laid out away from walls and obstacles.
- Pupils should be involved in assessing whether the activity area is safe in order to encourage future good safety practice.

Miscellaneous

- Sweets and chewing-gum should never be allowed in the work area.

Warm-Ups

Introduction

It is important that young people come to understand the importance of warming-up before and cooling down after activity so that they maintain good practice throughout their sporting lives.

In this section you will find a series of warm-up and cool down activities that have been designed to deliver to your class prior to and following any athletics lesson. In addition there are some specific warm-ups in the introductory sections. All of the warm-up activities are appropriate for students between the ages of 11 and 16 and for indoor or outdoor settings.

Warming-up

There are three different types of warm-up activities in this section:

Mobility Activities

- These are activities that mobilise the joints that students are going to use during the lesson in order to avoid injury. Some of them are compound activities that mobilise whilst gently raising the heart rate.

Pulse-Raisers

- These activities are designed to gradually increase the heart rate of the students and to warm up the large muscle groups.

Dynamic Stretching Activities

- These activities consist of controlled movement of parts of the body, gradually increasing reach and speed until the limit of the participant's range of motion is attained.
- Dynamic stretches require skill and control and should only be attempted by more able students and under close supervision.
- A large number of students are unable to perform dynamic stretches under control with good technique and through a full range of movement, therefore static stretches will probably still be needed to be performed in order to ensure they have stretched effectively. You should base the decision whether to stretch dynamically or not on the individual ability of the students. It is assumed at this level that students know how to carry out the basic static stretches.

It is recommended both for safety and in order to perform the optimum warm up, that your students start with a mobility activity, progress through to a pulse-raising activity and then finish with static and if they are sufficiently able, dynamic stretches.

Cooling Down

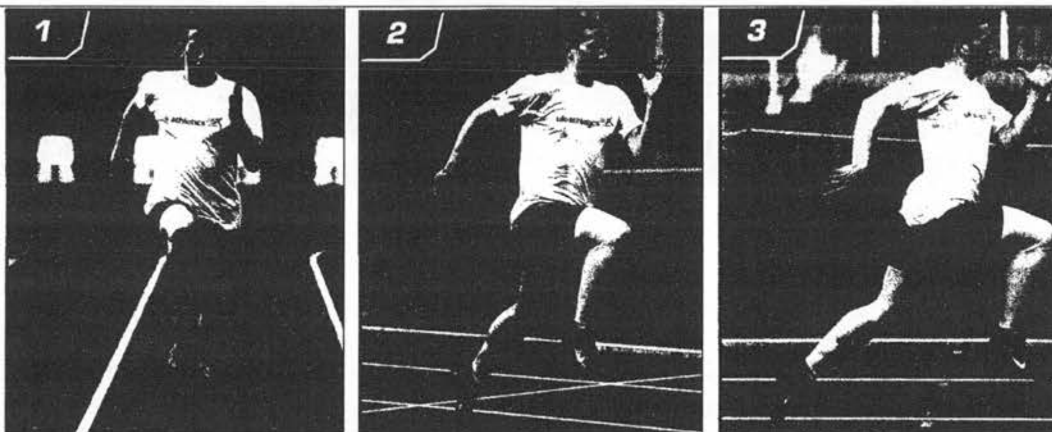
It is equally important that students cool down at the end of a session. It is recommended that students lower their pulse rate gradually to the pre-activity rate and then stretch. Mobility activities are not necessary.

Walking is the best way of slowing down the pulse rate. You might like to simply ask the class to form a circle and jog for a minute, progressively reducing speed and then walking for one minute before performing some stretches. The Pulse-Raiser activities can also be used for cooling down but they should be implemented inversely. For example, with Pulse-Raiser - "Sideways Shift", ask students to start with a skip and to gradually slow down to a walking pace.

When cooling down, intersperse static stretches with walking. You can even stretch the upper body whilst walking. This will ensure that the participants do not cool down too quickly. A full body stretch is recommended regardless of the athletic activity that has been participated in. Dynamic stretches are not appropriate for cooling down.

Running for Speed and Relay
Introduction

Sprinting is about reaching and maintaining a maximum speed over a comparatively short distance. When teaching sprinting it is important to encourage a good technique from the outset. The chart below details some teaching tips that you can use to help your students improve their sprinting technique. These suggestions can be practised in isolation or incorporated into the activities outlined later in this section.



'How to'	
The Torso The torso is kept straight with the head still and eyes focused ahead.	**Teaching tips** Ask students to keep their eyes on a fixed point.
The Driving Leg As soon as the foot leaves the ground, the driving leg bends and swings with the heel close to the sprinters body.	**Teaching tips** Ask students to run with an exaggerated flick up of their heels to their bottoms. Keep the steps small.
The Free Leg The free leg swings ahead of the sprinter until the thigh is parallel to the ground and then extends to touch the ground with a "down and back" motion.	**Teaching tips** Encourage students to run using short steps with their hands raised to chest height in front of the body, elbows bent and palms facing down. Students should lift their thighs up parallel to the ground so their knees touch their hands. Do not lean backwards.
Arms The arms are bent to about 90° and move in opposition to the legs in a fast relaxed action emphasising the drive backwards.	**Teaching tips** Explore with students running with the incorrect technique. Ask students to run using the same arm and leg, with folded arms, with straight arms, with their arms rotating like a windmill. Get them to compare this to the correct technique. Ask them which they find easier.

Jumping
Warm-Ups

The following warm-ups are for use in tandem with the mobility and stretching activities and pulse-raisers contained within the central warm-up and cool down section. The additional, jumping-specific activities contained here assist the introduction of the basic skills that will be taught within each lesson and develop the appropriate loco-motor skills.

Mirror Jump

Warm-Up Activity

11-14 14-16 INC

How to

- Split class into pairs and ask them to find themselves a space.
- Pairs should nominate one individual to lead first.
- The leader should experiment with three different hop, skip and jump sequences and their partner should then try to mirror the sequence they have performed, for example:
  - hop, hop, hop, jump
  - hop, hop, step, jump
  - jump, jump, hop, hop.

You will need

No equipment for this activity.

Differentiation

Wheelchair users can agree on a code with their partner for different types of pushes to represent a hop, a step or a jump.

Variation

Once students are comfortable with the format of the activity, the individual who is not leading might like to call out what they believe the sequence to be as their partner is executing it.

High Skip

Warm-Up Activity

11-14 14-16 INC

You will need

No equipment for this activity.

How to

- Split class into two groups and stand one group behind the other.
- At your command the first group of students should travel to the end of the activity area using a high skipping action.
- They should demonstrate a high, controlled bounce. At the height of each bounce the thigh of the raised leg should be parallel to the floor.
- Instruct students to keep their abdomens tucked in, their chins up and their body position tall.

When the first group reach the end of the activity area the second group can commence skipping.

Differentiation

- Wheelchair users might like to run the course using a succession of long pushes.
- Students who have limited lower body coordination can skip low.

Variations

- Students can travel back to the start line hopping or skipping low.
- Students can perform two star jumps when they reach the end of the course.

Jumping Warm-Ups

Hop, Stride, Hop, Stride

Warm-Up Activity

11-14 14-16 INC

How to

- Demonstrate the following sequence to students: hop, stride, hop, stride. Some may find this combination quite difficult. Students should hop on their take-off leg. The second hop should be on the other leg.
- Ask students to travel the length of the activity area repeating this sequence over and over in a fluid fashion.
- Instruct students to keep their abdomens tucked in, their chins up and their body position tall.

You will need

No equipment for this activity.

Differentiation

- Wheelchair users might like to run the course using a succession of long pushes.
- Students who have difficulty with coordinating themselves to begin with can walk through the sequence.

Header Jump

Warm-Up Activity

11-14 14-16 INC

You will need

2 foam balls

How to

- Split class into two groups and ask them to stand at one end of the activity area.
- The teacher should stand in the centre of the activity area with a foam ball in each hand with arms out to the sides and hands as high as they will go.
- At the teacher's command, the first individual from each group should jump two feet to two feet from the start point in the activity area and when they reach the teacher they should jump up to 'head' the foam ball. The teacher should let go of the ball so that the student heads it into free air.
- After they have headed the ball they should run back to the start line and the next pair can go.

Differentiation

- Lower the ball for wheelchair users and students who have difficulty with coordinating themselves.

Variations

- This can be done as pair work with students paired up so that they are not of too disparate heights.
- Students could jump and touch the ball with their hand rather than head it.

Jumping Warm-Ups

Jump Slalom

Warm-Up Activity

11-14 14-16 INC

How to

- Layout two lines of 10 cones approximately 60cm apart.
- Split class into two groups and ask them to stand in lines at one end of the activity area.
- At your command the first student at the front of each line should slalom between the line of cones in front of them using two feet to two feet jumps.
- When they reach the end of their course they can sprint back to the start line slaloming through the cones again.
- When they get back to the start line the next student can go.

You will need

20 cones.

Differentiation

- Wheelchair users can slalom through the cones using short pushes on their way to the end of the course and long pushes on their way back.

Variations

- To avoid a competitive element to this activity ask students to perform the return leg of the course walking.

Bench Step-Ups

Warm-Up Activity

11-14 14-16 INC

You will need

1 bench per pair
masking tape (optional).

How to

- Split the class into pairs and allocate each pair a bench.
- One student should start with two feet in front of the bench and step onto the bench with one foot.
- When the other foot has joined the first then they can step down again with the first foot.
- They should wait again for the other foot to join the first on the floor before repeating the action six times.
- After they have repeated the action six times they should start the pattern with the other foot.

Students should swap roles after this.

Differentiation

- Wheelchair users can move forwards and backwards over a line of masking tape, starting by moving forward for six moves and then by starting with a backwards movement for six moves.

Variations

- If you do not have enough benches you might like to split class into groups of four instead and have two individuals from each group speed bouncing either side of a strip of marking tape while their team mates work together on their bench step-ups.

(U.K.A.2006)

Appendix 10

The Session Plan

Session 1
20 metre relays
a) 1 x running
b) 1 x right foot hopping
c) 1 x left foot hopping
d) 1 x bunny hopping with two feet together
e) 1 x bunny hopping touching the ground between hops.
f) 1 x sprint race

4 x 10 each hand crushing the tennis ball.

Session 2
Bench straddle jumps (stand on the bench, jump down onto the floor straddling the bench, sit on the bench, and then jump back on the bench).

Repetitions = Week Number x 4.
Repetitions = Week Number x 6.
Repetitions = Week Number x 10.
Repetitions = Week Number x 15.
Repetitions = Week Number x 20.

Croydon, the Centre of the Research

(From www.croydon.gov.uk)

Croydon is the economic and social capital of the South East of England, with an international profile and diverse business interests, including the largest shopping centre in the South East. With a population of 330,700 it is the most populated London borough.

Transport

Croydon has excellent road, rail and air connections providing first class transport links to London, the UK and overseas. Bus services are extensive. We also have Tramlink, a 28 kilometre environmentally friendly light rail service which links with New Addington, Beckenham, Elmers End and Wimbledon.

Housing

Croydon offers a broad choice of residential property from town houses and modern apartments to prestige homes in countryside settings.

Education

The Council runs 6 nursery schools and early years centres, 94 primary schools, 23 secondary schools, 6 special schools and 3 colleges. Our Continuing Education & Training Service provides a variety of adult education and business training courses to over 32,000 students each year. The Brit School is the only free performing arts school in Britain, catering for over 750 students aged between 14 and 19.

Entertainment

Croydon has a wide range of dining options, bars and nightclubs. All ages and tastes are catered for. We are one of the liveliest and best served centres of culture in the London area.

Leisure

We have over 2,600 acres of parkland and open spaces .Our rich inheritance comprises over 120 parks and nature reserves offering the widest possible range of sports and leisure. The surrounding fields and woods of the North Downs provide a natural framework around the borough.

Croydon is home to Crystal Palace football club, who play at Selhurst Park. The Council provides a very wide range of sports and recreational activities including four swimming pools. The Crystal Palace National Sports Centre is one of the country's premier athletics stadia.

Croydon has two full championship golf courses, seven 8 hole courses, pitch and putt courses and driving ranges. Sailing and canoeing are available at the South Norwood Country Park. Croydon enjoys 20km of the London Loop and 34km of bridleway for horse riding and cycling.

Numerous fitness clubs and sports complexes thrive in central Croydon and around the borough. The Croydon Sports Partnership promotes and develops sport for young people and is one of the first initiatives of its kind in the UK.

(Croydon Council 2009)

The Schools

Primary and Junior Schools in the London Borough of Croydon

All Saints CE Junior School, Upper Beulah Hill, Upper Norw'd.	020 8771 9439
Applegarth Junior School, Bygrove, Fieldway, New Addington.	01689 841529
Ashburton Junior School, Long La, Croydon.	020 8654 3594
Atwood Primary School, Limpsfield Rd, South Croydon.	020 8657 7374
Beaumont Primary School, Old Lodge Lane, Purley.	020 8660 7707
Beddington Park Primary School, Derry Rd, Croydon.	020 8688 1390
Benson Primary School, West Way, Croydon.	020 8777 1572
Beulah Junior School, Beulah Rd, Thornton Heath.	020 8653 4921
Broadmead Junior School, 366, Sydenham Rd, Croydon.	020 8689 5473
Byron Junior School, St David off Stoneyfield Road, Coulsdon.	020 8668 4877
Castle Hill Primary School, Dunley Dr, New Addington.	01689 843148
Castle Hill Primary School, Dunley Dv, New Addington.	01689 842002
Chipstead Valley Primary School, Chipstead Vlly Rd, Coulsdon.	01737 553255
Christ Church C of E Primary School, Montpelier Rd, Purley.	020 8660 7500
Coulsdon C of E Primary School, Bradmore Green, Coulsdon.	01737 554789
Courtwood Primary School, Court Wood Lane, Croydon.	020 8657 8454
Cypress Junior School, 32, Cypress Rd, SE25.	020 8653 2618
David Livingstone Primary School, Northwood Rd, Th'n Heath.	020 8653 4240
David Livingstone School, 171, Northwood Road, Th'n Heath.	020 8653 4240
Davidson Junior School, Dartnell Rd, Croydon.	020 8656 4572
Davidson Primary School, Dartnell Road, Croydon.	020 8654 1460
Downsview Primary & Nursery School, Biggin Way, SE19.	020 8764 4611
Duppas Junior School, Goodwin Road, Croydon.	020 8688 4975
Ecclesbourne Junior School, Attlee Clo, Thornton Heath.	020 8684 5704
Elmhurst School for Boys, 44-48, South Park Hill Rd, Croydon.	020 8688 0661
Elmwood Junior School, Lodge Rd, Croydon.	020 8684 4007
Fairchildes Primary School, Fairchildes Avenue, N. Addington.	01689 842268
Forestdale Primary School, Woodpecker Mount, Croydon.	020 8657 0924
George William Foundation The, 327 Bensham La Th'n Heath	020 8665 5066
Gilbert Scott Community School, Farnborough Av, Croydon.	020 8657 4742
Gilbert Scott Junior School, Farnborough Av, South Croydon.	020 8657 4742
Gonville Primary School, Gonville Rd, Thornton Heath.	020 8684 4006
Good Shepherd RC School, Dunley Drive, New Addington.	01689 841771
Greenvale Primary School, Sandpiper Rd, South Croydon.	020 8651 2833
Gresham Primary School, Limpsfield Rd, South Croydon.	**020 8657 1807**
Hayes Primary School The, 98, Hayes La, Kenley.	020 8660 4863
Heavers Farm Primary School, 58, Dinsdale Gardens, SE25.	020 8653 5434
Howard Primary School, Dering Pl, Croydon.	020 8688 4216
Kenley Primary School, New Barn Lane, Whyteleafe.	020 8660 7501
Kensington Avenue Junior, School, Kensington Av, Th'n Heath.	020 8764 2923
Keston Primary School, Keston Av, Coulsdon.	**01737 555103**
Kingsley Primary School, Thomson Cres. Croydon.	020 8689 7688
Link Day School, The, 138, Croydon Rd, Beddington.	**020 8688 5239**
Margaret Roper Catholic Primary School, Russell Hill, Purley.	020 8660 0115

Monks Orchard Primary School, The Glade, Croydon.	020 8654 2570
Orchard Way Primary School, Orchard Way, Croydon.	020 8777 6111
Oval Primary School, 98, Cherry Orchard Road, Croydon.	**020 8688 3000**
Parish Church C of E Junior School, Warrington Rd, Croydon.	020 8688 5764
Park Hill Junior School, Stanhope Rd. Croydon.	020 8686 8623
Purley Oaks Primary School, Bynes Rd, South Croydon.	020 8688 4268
Regina Coeli Primary School, 173 Pampisford Rd, Croydon.	020 8688 4582
Ridgeway Primary School, Southcote Rd, South Croydon.	020 8657 6957
Ridgeway Primary School, Southcote Rd, South Croydon.	020 8657 8063
Rockmount Junior School, Rockmount Rd, SE19.	020 8653 4768
Rockmount School, Chevening Rd, London.	020 8653 2619
Roke Primary School, 51, Little Roke Rd, Kenley.	020 8660 2714
Rowdown Primary School, Calley Down Cres, N. Addington.	**01689 843367**
Ryelands Primary School, Albert Rd, SE25.	020 8656 4165
Selsdon Primary School, Addington Rd, South Croydon.	020 8657 4038
Smitham Primary School, Portnalls Rd, Coulsdon.	020 8660 4399
South Norwood Primary School, 34, Crowther Rd, SE25	020 8654 2983
Spring Park Primary School, Bridle Rd, Croydon.	020 8777 6482
Spring Park Primary School, Bridle Road, Croydon.	020 8777 2808
St Aidans RC Primary School, Portnalls Rd, Coulsdon.	01737 556036
St Chads R C Primary School, Alverston Gardens, SE25	020 8771 3470
St Cyprians Primary School, 53, Springfield Road, Th'n Heath.	020 8771 5425
St James the Great RC Primary 75.Windsor Road, Th'n Heath.	020 8771 3424
St Johns CE Primary School, Spring Park Rd, Croydon.	020 8654 2260
St Joseph's RC Junior School, 20.Woodend, London.	020 8653 7195
St Mark's C of E Primary School, Albert Rd, SE25.	020 8654 3570
St Marys R C Junior School, Sydenham Rd, Croydon.	020 8688 4893
St Peter's Primary School, Normanton Rd, South Croydon.	020 8688 5414
St Thomas Becket R C School, Becketts Close, SE25.	020 8654 3006
St. Davids School, 23-25, Woodcote Valley Rd, Purley.	020 8660 0723
Tollgate Primary School, Malling Close, Croydon.	020 8656 3720
Wattenden School, The, Old Lodge La. Purley.	020 8660 1325
West Dene School, 167, Brighton Rd, Purley.	020 8660 2404
West Thornton Primary School, Rosecourt Rd, Croydon.	020 8684 3497
Whitehorse Manor Junior School, Whitehorse Rd, Th'n Heath.	020 8684 3929
Winterbourne Junior Boys Sch, Winterbourne Rd, Th'n Heath.	020 8689 7685
Winterbourne Junior Girls Sch, Winterbourne Rd, Th'n Heath.	020 8684 3532
Wolsey Junior School, King Henrys Dr, New Addington.	**01689 843103**
Woodcote Junior School, Dunsfold Rise, Coulsdon.	020 8668 3374
Woodside Junior School, Morland Road, Croydon.	020 8654 5333

(acquired from numerous sources)

Gresham Primary School

Type of school	Primary
School category	Community
Age range of pupils	4 to 11
Gender of pupils	Mixed
Number on roll	212
Appropriate authority	The governing body
Date of previous inspection	19 October 2005
School address	Limpsfield Road Sanderstead South Croydon, Surrey CR2 9EA
Telephone number	020 8657 1807
Fax number	020 8657 1686
Chair of governors	Mr C Locke
Headteacher	Mrs L Benton

Introduction
The inspection was carried out by two Additional Inspectors.

Description of the school
Gresham is an average-sized primary school. About three quarters of its pupils are of White British heritage and the remainder are from a wide range of ethnic and linguistic backgrounds. The number of pupils eligible for free school meals is lower than the national average. The number of pupils with learning difficulties and/or disabilities is average, although the number of pupils with statements of special educational need and high levels of learning disorders and/or physical need is above average. There is before and after school provision on the school site, managed by the governing body.

Overall effectiveness of the school

Grade: 2 Good (Ofsted 2009)

Keston Primary School

Type of school	Primary
School category	Community
Age range of pupils	3–11
Gender of pupils	Mixed
Number on roll (school)	478
Appropriate authority	The governing body
Date of previous school inspection	Not previously inspected

School address	Keston Avenue Old Coulsdon Coulsdon CR5 1HP
Telephone number	01737 555103
Fax number	01737 550851
Chair	Mrs Miriam Massey
Headteacher	Mrs Linda Hall

Introduction

The inspection was carried out by three Additional Inspectors.

Description of the school

Keston is a large primary school situated in a residential area in the south of Croydon. It was formed in September 2003 following the amalgamation of the Infant and Junior schools. There are a funded nursery and an extended care facility on site. Over four fifths of pupils are of British White origin. The proportion of pupils with English as an additional language is below average, the most common languages being Tamil, Spanish and Cantonese. A below average proportion of pupils is entitled to free school meals. The number of pupils with learning difficulties and disabilities and the number with statements of special educational need are below average.

Overall effectiveness of the school

Grade: 1 Outstanding (Ofsted 2009)

Oval Primary School

Type of school	Primary
School category	Community
Age range of pupils	3-11
Gender of pupils	Mixed
Number on roll (school)	369
Appropriate authority	The governing body
Date of previous school inspection	21 November 2006

School address	98 Cherry Orchard Road Croydon CR0 6BA
Telephone number	020 8688 3000
Fax number	020 8680 3435
Chair	Mrs Doreen Ridden
Headteacher	Mrs Kate Toope

Introduction

The inspection was carried out by three Additional Inspectors.

Description of the school

Pupils attending this above average-sized school are drawn from a wide range of ethnic backgrounds. A very high proportion of pupils are from homes where English is not the first language. A below average proportion of pupils have learning difficulties and disabilities. Learning difficulties are mainly related to dyslexia, speech, language and communication, behaviour and emotional and social needs. The take up of free school meals is above average. The proportion of pupils joining and leaving the school at unusual times is above average. Staff turnover has also been high, and the school has found it difficult to recruit experienced teachers. When the school was inspected in November 2006 it was judged to require significant improvement and was given a Notice to Improve.

Overall effectiveness of the school

Grade: 3 Satisfactory (Ofsted 2009)

Rowdown Primary School

Type of school	Primary
School category	Community
Age range of pupils	3–11
Gender of pupils	Mixed
Number on roll (school)	359
Appropriate authority	The governing body
Date of previous school inspection	7 October 2002

School address	Calley Down Crescent New Addington Croydon CR0 0EG
Telephone number	01689 843367
Fax number	01689 843523
Chair	Nathan O' Gilivie
Headteacher	Mrs Linda Shute

Introduction

The inspection was carried out by three Additional Inspectors.

Description of the school

Rowdown is an above average sized school that serves a community recognised as having high levels of social deprivation. Most pupils are from White British backgrounds. Very few pupils speak another language other than English. The proportion of pupils with learning difficulties and disabilities is above average. Children enter the nursery with attainment that is well below that found nationally. The proportion of teachers leaving and joining the school during the last two years is high.

Overall effectiveness of the school

Grade: 3 Satisfactory (Ofsted 2009)

Wolsey Junior School

Type of school	Junior
School category	Community
Age range of pupils	7-11
Gender of pupils	Mixed
Number on roll (school)	353
Appropriate authority	The governing body
Date of previous school inspection	17 September 2001

School address	King Henry's Drive New Addington Croydon CR0 0PH
Telephone number	01689 843103
Fax number	01689 843346
Chair	Mrs P Williams
Headteacher	Mrs A Daly

Introduction
The inspection was carried out by three Additional Inspectors.

Description of the school
The school is larger than average and is set in an area of Croydon where deprivation is greater than is usually found. The proportion of pupils entitled to free school meals is very high. Pupils come from diverse cultural backgrounds although most are from White British backgrounds. The next largest groups include pupils from Black African and Black Caribbean heritages. Only a few pupils are at an early stage of learning to speak English as an additional language. More pupils than usual have learning difficulties or disabilities. Since the last inspection, the school has experienced some disruption due to leadership and staffing difficulties. An acting headteacher took over the running of the school in January 2007. The school holds the Healthy Schools award and the Activemark.

Overall effectiveness of the school

Grade: 3 Satisfactory (Ofsted 2009)

Ethics Committee Application Form

University of Edinburgh

MORAY HOUSE SCHOOL OF EDUCATION
ETHICS COMMITTEE

Application Form
(This form is for completion electronically)

SECTION 1: PROJECT DETAILS

1.1	Title of Project	Measuring strength as a precursor to conditioning designed to eliminating weakness as an intervention in cases of D.C.D.
1.2	Proposed start date	1/6/04
1.3	Duration of the project	3 months

1.4 List the following details of the Principal Investigator, and any Co-Investigator(s)

Principal Investigator

Name: David Collins
Title: Professor
Department: Physical Education, Sport and Leisure Studies
Address: St Leonard's Land, Holyrood Road, EDINBURGH. EH8 8AQ.

Tel: 0131 651 6523 Email: d.collins@education.ed.ac.uk

Co- Investigator

Name: Geoffrey Platt
Title: Mr
Department: Physical Education, Sport and Leisure Studies
Address: 47, Heathhurst Road, SANDERSTEAD, Surrey. CR2 0BB.

Tel: 07768 727205 Email: GeoffPlatt@aol.com

Co-Investigator

Name: Gerd-Jan Pepping
Title: Dr
Department: Physical Education, Sport and Leisure Studies
Address: St Leonard's Land, Holyrood Road, EDINBURGH. EH8 8AQ.

Tel: 0131 651 6135 Email: g.j.pepping@ed.ac.uk

1.5 If funding is necessary to proceed with the study, has it been secured? YES □ NO X

If YES, give details of the agency/agencies supporting the project. If a funding submission is planned, give details of the agency/agencies to which a funding application(s) has been made.

1.6 Does the project require the approval of any other institution and/or ethics committee?

YES □ NO X

If YES, give details and indicate the status of the application at each other institution or ethics committee (i.e. submitted, approved, deferred, rejected).

SECTION 2: DESCRIPTION OF THE RESEARCH

Please give a brief description of the project. This should include, as appropriate, the aims and objectives of the study, the research question and/or hypothesis to be investigated, details of the sample, and data collection methods.

Method

Participants

Participants were one hundred primary school children taken from eight different classes at two different schools. They were of mixed gender and ethnicity and aged between seven and nine years. The Movement A.B.C. test was used to identify the participants with Developmental Coordination Disorder (D.C.D.) and to compare their results with the remaining members of the classes. The Movement A.B.C. is statistically adjusted to produce a positive result in 5% of cases; thus 5 children were identified with the effects of D.C.D. whilst 95 were identified as without those effects. Children with D.C.D. are recognised to avoid sporting classes and activities. Accordingly, attendance history was researched, incentives to participation were supplied and all absences from the class lists were investigated.

The written consent of the parents, the school principal and the teaching staff were obtained for all sessions to be video recorded so as to deal with any child protection concerns.

Tests and Instrumentation

The present study utilised a range of strength tests, selected to offer a continuum ranging from simple single-joint exercises to complex multi-joint exercises. The tests selected were as follows:

1. Grip dynamometer

A standard Monarch grip dynamometer was used. The students raised the dynamometer above their head at arm's length, maximally squeezed the grip and lowered the dynamometer at arm's length continuing to maximally squeeze it until it rested against their legs. The participant was encouraged to naturally select their favoured (and probably strongest) hand.

2. Leg and back dynamometer

A standard leg and back dynamometer was used. The students stood on the platform of the dynamometer and took hold of the handle, with legs bent and back straight. They then straightened their legs and extended their back to stand upright against the resistance provided by the dynamometer.

3. Sargeant jump

A standard belt and rope sargeant jump machine was employed. The participants stood on the platform and attached the belt around their waist. They then bent their legs and vigorously straightened them to jump as high as they were able. The height achieved was measured by the Sargeant Jump machine.

4. Triple two-footed standing broad jump

The participants stood behind a line and without bending their legs excessively took three, two-footed standing broad jumps. All efforts were measured using a standard tape measure. Jumps were measured from take off to landing.

The Movement ABC test was performed according to the current protocols.

Finally, teacher ratings were obtained of each child's movement ability. A simple 'A to E' scale was used, with a grade of C reflecting, in the teacher's experience, an average level of motor competence for that particular age group and gender. In addition, in order to control for potentially extraneous influences, demographic data encompassing birth order, number of siblings, ethnicity, general health, age and gender were collected.

Procedures

Data were collected during normal scheduled P.E. classes. The classes were informally structured, however, and avoided the usual requirement for students to change into sports kit, which may have had the effect of upsetting children with D.C.D. and causing them to withdraw from further participation. The same researcher and assistants performed all measurements.

Initially, all students completed a short demographics questionnaire, and received a briefing on the purposes of the investigation. The four strength tests were then completed in sequence. Each activity started with a demonstration and explanation, followed by two practice attempts and two measured attempts for each participant, with the better result in each activity being counted. Following this, all students completed the ABC test.

Design.
For each test, the dependant variable was the performance measure, standardised through use of a z score calculated across the whole sample. Analysis was by means of two mixed design MANOVAs, using the four levels of strength test as a within subjects measure. In the first, four quartile groups were defined as the between subjects factor, using the ABC scores supplemented by the teachers ratings to define the groups. In the second, we focussed specifically on the lower ability children, using four equal groups from the lowest attainment on these two discriminating factors. This provided one DCD group, then three other equally sized groups of increasing (although still low level) motor competence.

Specifically, we were interested in the tests discrimination between the groups. In the first case, the extent to which strength uniformly improved from group to group, whilst in the second, the extent to which between groups differences varied systematically across the low ability groups.

SECTION 3: POTENTIAL RISKS TO PARTICIPANTS

3.1 Could the research induce any psychological stress or discomfort? YES ☐ NO X

If YES, state the nature of the risk and what measures will be taken to deal with such problems.

3.2 Does the research require any physically invasive or potentially physically harmful procedures? YES ☐ NO X

If YES, give details and outline procedures to be put in place to deal with potential problems.

3.3 Does the research involve the investigation of any illegal behaviours? YES ☐ NO X

If YES, give details.

3.4 Is it possible that this research will lead to the disclosure of information about child abuse or neglect?

YES ☐ NO X

If YES, indicate the likelihood of such disclosure and your proposed response to this. If there is a real risk of such disclosure triggering an obligation to make a report to Police, Social Work or other authorities, a warning to this effect must be included in the Information and Consent documents.

3.5 Is there any purpose to which the research findings could be put that could adversely affect participants?

YES X NO ☐

If YES, describe the potential risk for participants of this use of the data. Outline any steps that will be taken to protect participants.

The research will identify children with Developmental Coordination Disorder. All records of the investigation will be kept confidential to the researchers and only the collected results will be published.

3.6 Could this research adversely affect participants in any other way? YES ☐ NO X

If YES, give details and outline procedures to be put in place to deal with such problems.

3.7 Could this research adversely affect members of particular groups of people?

YES ☐ NO X

If YES, describe these possible adverse effects and the protection to be put in place against them.

3.8 Is this research expected to benefit the participants, directly or indirectly?

YES X NO ☐

If YES, give details.

As a result of this research advice can be given to children with D.C.D., to their parents and their teachers. When the research is complete more will be known about the condition and possible interventions.

3.9 Will the true purpose of the research be concealed from the participants? YES ☐ NO X

If YES, explain what information will be concealed and why. Will participants be debriefed at the conclusion of the study? If not, why not?

SECTION 4: PARTICIPANTS

4.1 How many participants is it hoped to include in the research?

4.2 What criteria will be used in deciding on the inclusion and exclusion of participants in the study?

4.3 Are any of the participants likely to:

be under 16 years of age?	YES X	NO □
children in the care of a Local Authority?	YES □	NO X
known to have special educational needs	YES □	NO X
physically or mentally ill?	YES □	NO X
vulnerable in other ways	YES □	NO X
members of a racial or ethnic minority?	YES X	NO □
unlikely to be proficient in English?	YES □	NO X
in a client or professional relationship with the researchers?	YES □	NO X
in a student-teacher relationship with the researchers?	YES X	NO □
in any other dependent relationship with the researchers?	YES □	NO X
have difficulty in reading and/or comprehending any printed material distributed as part of the study?	YES □	NO X

If YES to any of the above, explain and describe the measures that will be used to protect and/or inform participants.

The research will be conducted in and around Lambeth in South London, a racially mixed area. It will be undertaken during normal Physical Education lessons and in the presence of their regular P.E. staff, who will be available to intervene in case of any problems.

4.4 How will the sample be recruited?
By agreement with staff and with written parental consent.

4.5 Will participants receive any financial or other material benefits because of participation?
YES □ NO X

If YES, what benefits will be offered to participants and why?

Before completing Sections 5 & 6 please refer to the University Data Protection Policy to ensure that the relevant conditions relating to the processing of personal data under Schedule 2 and Schedule 3 are satisfied. Details are Available at:

http://www.dataprotection.ed.ac.uk/principles.html
http://www.dataprotection.ed.ac.uk/activities/DPPolicyFINAL.htm

SECTION 5: CONFIDENTIALITY AND HANDLING OF DATA

5.1 Will the research require the collection of personal information from e.g. universities, schools, employers, or other agencies about individuals without their direct consent?

YES □ NO X

If YES, state what information will be sought and why written consent for access to this information will not be obtained from the participants themselves.

5.2 Will any part of the research involving participants be audio/film/video taped or recorded using any other electronic medium?

YES X NO □

If YES, what medium is to be used and how will the recordings be used?

It is intended to digitally video record participants because xxxxxxxxxxx

5.3 Who will have access to the raw data? Only the research team.

5.4 How will the confidentiality of data, including the identity of participants, be ensured? All data will be the personal responsibility of one researcher, Geoffrey Platt.

5.5 Specify where the datafiles/audio/video tapes, etc. will be retained after the study, how long they will be retained and how they will eventually be disposed of.
XXXXXXX

5.6 How do you intend for the results of the research to be used?

5.7 Will feedback of findings be given to participants. YES □ NO X

If YES, how and when will this feedback be provided?

SECTION 6: PARTICIPANT INFORMATION AND CONSENT

6.1 Will written consent be obtained from participants?

YES X NO □

If YES, attach a copy of the information sheet and consent forms.

If NO, explain why not.

Administrative consent may be deemed sufficient:

a) for studies where the data collection involves aggregated (not individual) statistical information and where the collection of data presents:

(i) no invasion of privacy;
(ii) no potential social or emotional risks:

b) for studies which focus on the development and evaluation of curriculum materials, resources, guidelines, test items, or programme evaluations rather than the study, observation, and evaluation of individuals.

6.2 Will administrative consent (eg. from a headteacher) be obtained in lieu of participants' consent? YES □ NO X

If YES, explain why individual consent is not considered necessary.

6.3 In the case of minors participating in the research on an individual basis, will the consent or assent of parents be obtained? YES X NO □

If YES, explain how this consent or assent will be obtained.

If NO, give reasons.

6.4 Will the consent or assent (at least verbal) of minors participating in the research on an individual basis be obtained?

YES □ NO X

If YES, explain how this consent or assent will be obtained.

If NO, give reasons.

6.5 In the case of participants whose first language is not English, will arrangements be made to ensure informed consent?

YES □ NO X

If YES, what arrangements will be made?

If NO, give reasons.

6.6 In the case of participants with special educational needs will arrangements be made to ensure informed consent?

YES □ NO X

If YES, what arrangements will be made?

If NO, give reasons.

SECTION 7: CONFLICT OF INTEREST

The University has a draft 'Policy on the Conflict of Interest' (copies available from the Research Support Office). Regarding research the draft states that a conflict of interest would arise in cases where an employee of the University might be

> **" compromising research objectivity or independence in return for financial or non-financial benefit for him/herself or for a relative or friend."**

The draft policy also states that the responsibility for avoiding a conflict of interest, in the first instance, lies with the individual, but that potential conflicts of interest should always be disclosed, normally to the line manager or Head of Department. Failure to disclose a conflict of interest or to cease involvement until the conflict has been resolved may result in disciplinary action and in serious cases could result in dismissal.

7.1	Does your research
involve a conflict of interest as outlined above	YES☐ NO X

If YES, give details.

Electronically completed forms should be submitted to Sandra.Orr@ed.ac.uk Research Support Office, Old Moray House, Moray House School of Education together with a completed and signed hard copy of the **Approval Request Form** (below)

UNIVERSITY OF EDINBURGH

MORAY HOUSE SCHOOL OF EDUCATION

ETHICAL APPROVAL OF RESEARCH

Approval Request Form

This form together with the **Application Form** should be used for all research carried out under the auspices of Moray House School of Education. A three-tier system of ethical approval has been developed, administered by the Ethics Sub-committee and the Research Support Office. The levels within the system are explained below. Please tick the appropriate box to indicate which level applies to your research.

All applications should be submitted well in advance of a required date of approval, particularly in the case of Level 3. Applications will normally be processed within 2-4 weeks, but this cannot be guaranteed.

Level 1: applies to 'straightforward' non-intervention, observational research (e.g. analysis of archived data, classroom observation, use of standardised questionnaires).	
Level 2: covers novel procedures or the use of atypical participant groups - usually projects in which ethical issues might require more detailed consideration but were unlikely to prove problematic.	
Level 3: applies to research which is potentially problematic in that it may incorporate an inherent physical or emotional risk to participants.	

Colleagues are reminded that all researchers working directly with children and other groups as listed in 4.3 in the application form should ensure they have prior Disclosure Scotland clearance (formerly Scottish Criminal Record Office). This is a confidential process and forms are available from Karen Derrick, Faculty Office. Members of staff who have **current** clearance through GTC membership are already covered.

This form must be signed by the member of staff undertaking the research and their Head of Department. Applicants must indicate their commitment to following the ethical guidelines appropriate to their research (e.g. BERA, BSA, BPS, BASES).

Name... **Signature............................**

Ethical guidelines followed...

Head of Dept Signature ....

Date................

Appendix 14

Ethics Committee Response

Dear Geoff

Thank you for submitting an ethical application form - this professional and responsible approach to your research is appreciated and recognised. The School Ethics Committee has now had an opportunity to consider your application and their comments and queries are listed below. The comments reflect the importance of covering all potentially problematic ethical areas in research, which as you are aware is for the benefit and safety of all involved - both researcher and participants. When issues are raised in an ethical application form they should be viewed positively as they can help strengthen research as well as introducing another view point. The Committee recommend that you discuss your application and the Committee's comments with your supervisor.

Comments
Section 2 - The committee queried what 'statistically adjusted to produce a positive result in 5% cases' means. Who does the adjusting - the experimenter or the actual test questionnaire? Can you get the possibility that 0 children out 100 will have DCD or 25 will have it? What happens to the research then? Is this test just checking against a standardized percentile?

A 20 metre bleep test is usually maximal exercise. This needs to be stated and the risks associated with it discussed. The committee would like to see some supporting evidence (ie papers) that this test is appropriate for use with 8-10 year old children and a clear statement of any risks involved.

Resistance training implies weights - are these exercises going to use free weights or just body weight? Whatever the answer, these tests might be maximal as well (suppose the children cannot do the correct number of reps because it is too hard?).

Need much clearer information (described in terms a layperson can understand) on procedures such as e.g. 20 metre bleep test. It's also not very clear how the training sessions are ramped up - 'increasing the repetitions by 2' could refer to either the '2' or the '12' in 2x12 etc but with very different numbers resulting. More detail needed on content of child briefing.

3.1 The committee did not agree that the research could be guaranteed not to cause psychological stress and felt that the responses to this and 3.2 required both clearer and more considered responses. Given that section 2 states that 'children with DCD are recognised to avoid sporting classes and activities' and 'the effect of upsetting children with DCD and causing them to withdraw from further participation', more details are needed about reassurance of children etc.

3.2 See comments above. The Bleep test is a maximal test and the resistance training might be.

3.5 Given that the K-ABC will identify only a small number of children with DCD (and that number could be v. small indeed), any advice given on the basis of the strength data in relation to possible associated learning difficulties could not be recommended.

3.9 If data are to be collected during normal PE classes, won't the children see each other perform and evaluate their performances? Or are children going to be tested individually, away from their classmates?

3.9 Hard to see how comment on children not being informed directly about their own performance or that of their peers can be justified.

4.3 Not sure what ' a part of the class' means in relation to likelihood of participants having difficulty in understanding printed study materials - presumably that within a sample of 100, bound to be some children with these difficulties?

4.4 Child consent is covered a little too loosely. The first phase could perhaps go through on parental and administrative consent, but the training phase requires more than that (6.1 refers to written consent being obtained from participants but the info/consent sheets are currently for parents only).

5.5 More details about place of storage (locked filing cabinet?) and disposal (how done) needed.

5.5 Retention of data for 5 years would be safer as some journals require this.

6.4 Children will need to be made explicitly aware and reassured of their rights not to participate and to withdraw at any stage. This may not be the same as usual PE classes (i.e. attendance at school is compulsory, research is not.).

6.5 and 6.6. Not enough here at all. If DCD does link to special needs, then this must be taken into account. Because DCD is being targeted, normal school procedures may not be enough.

Consent letter
Nowhere else does the proposal or consent letter mention clumsiness. This should be replaced with DCD as clumsiness could be seen to be judgemental.

The letter should include reassurance for parents that if their child is included in the study, this does not mean that he/she has DCD. A sentence about 'this study needs to investigate children of all abilities' or something similar should be included to ensure that parents do not jump to the conclusion that their child has DCD if they are in the study.

There is some confusion regarding the role of researcher and the suggestion that researcher is willing to talk to parents about mobility of their children should be removed.

You also need to consider consent materials for children and how you are ensuring that they are indeed willing to opt into the research. All of the children also need to be made aware that they can stop at any time. Priscilla Anderson's work on research ethics with children might be helpful here. 'Ethics, social research and consulting with children and young people', Social Science Research Unit and Barnardo's.

Info sheet: We don't have a Dept of Sport Science (as in header). There is also no mention anywhere of the training element of the study. Nor is there any indication of rights to withdraw at any time.

Disclosure Scotland. Any research work involving children or young adults requires clearance from Disclosure Scotland. Students in the School of Education apply through Karen Derrick, School Office, Old Moray House (email Karen Derrick (First Class) Tel: 51 6516).

I hope you don't find the length of this list too daunting - I'm sure you will appreciate that the committee's feedback is intended to be constructive and assist your future work.

Regards

Sandra Orr
Administrative Officer
University of Edinburgh
Research Support Office
Moray House School of Education, Holyrood Road, Edinburgh, EH8 8AQ
Tel: 0131 651 6386

This message has been created using voice recognition software. Please excuse any spelling mistakes that may have been missed.

Appendix 15

Introductory Email sent to all Primary Schools in the London Borough of Croydon on 4th September 2008.

Re: Clumsy Child Syndrome or Dyspraxia

Sir or madam,

I am a local teacher who is looking to help children with clumsy child syndrome or dyspraxia.

I have found a way to help these children through specific, but middle-of-the road exercise programmes that fit easily into the P.E. programme. Initial results have been very positive.

The work is being supervised by the University of Edinburgh as part of a PhD programme.

I have taken a sabbatical for the year in order to complete my research and am prepared to work without payment at local schools, teaching P.E. and pursuing this research.

I would like the opportunity to meet with you to discuss opportunities.

Thank you.

Geoffrey Platt

Appendix 16

Letter to Parents

Dear Parent/Guardian,

My name is Geoffrey Platt and I have been asked to tell you a little bit about myself. I am the Director of Coaching of British Weightlifting and also the Performance Director for Surrey Athletics. I have been selected to officiate at two Olympic Games and six Commonwealth Games.

I am researching into D.C.D. or clumsy child syndrome and I have spoken to the school about doing some movement and skill testing with the children. I work as a P.E. and sports teacher and I would like to work with the children during their P.E. lessons. I would measure their performance in the following tests:

1. Grip test
2. Leg and back test
3. Sargeant jump
4. Triple jump

I will also, with your permission, take them through the Movement ABC test, to identify those who are clumsier than the others. The results of these tests will be completely private and confidential. I am interested in the results of the group as a whole, rather than those of any individual and no child will be identified in any way.

The Movement ABC test consists of:

1. Shifting Pegs by Rows
2. Threading Nuts on Bolt
3. Flower Trail
4. Two hand Catch
5. Throwing Bean bag into Box
6. One-Board Balance
7. Hopping in Squares
8. Ball Balance

I will also use a device the size of a mobile telephone attached to a lightweight belt which is worn around the waist to measure the jerkiness (entropy) of the children's movements whilst walking across the gymnasium.

If any of you have concerns about your child's movement skills, I will be more than happy to discuss this with you privately and give you any advice that you may need.

I cannot and will not go ahead with my research without your consent and if you wish to withdraw your consent you may do so at any time. If you have any questions or comments, I will be pleased to speak to you.

Best wishes.

Researcher: Geoffrey Platt
GeoffreyKPlatt@ed.ac.uk
Telephone: 07768 727205

Figure 1

Movement ABC Photo Album

<table>
<tr><td>Manual Dexterity (Fine Motor Skills)

Shifting Pegs by Rows
This boy is moving pegs across the board. For this task, we test how well the children perform with both their dominant and non-dominant hands.</td><td>Threading Nuts on Bolt
Here the boy is threading three nuts onto a bolt. We give him two go's at this.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Flower Trail
For this task, the child is asked to draw between two lines. Our subject focuses intently on his drawing.</td><td>Ball Skills (Throw and Catch)
Two-hand Catch
Here we throw the ball against the wall and catch it.</td></tr>
<tr><td></td><td></td></tr>
</table>

<table>
<tr>
<td>Throwing Bean bag into Box
One of the tasks in our Movement ABC test is to throw a bean bag into a bin.</td>
<td>Dynamic Balance
One-board Balance
"WHOA!!!!" As is demonstrated in this picture, it is quite difficult to stand on one foot on this block for very long. Don't worry folks, no children were injured in the making of this picture.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopping in Squares
One hop in each square. No more; no less.</td>
<td>Ball Balance
"All I have to do is keep this tennis ball on top of this board? No problem."</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</table>

Figure 2

Entropy Testing Equipment

Figure 1. Front view of child wearing belt

Figure 2. Back view of child wearing belt

Figure 3. Side view of child wearing belt

Figure 4. Control box of belt.

Figure 2

Entropy Testing Equipment

Figure 1. Front view of child wearing belt

Figure 2. Back view of child wearing belt

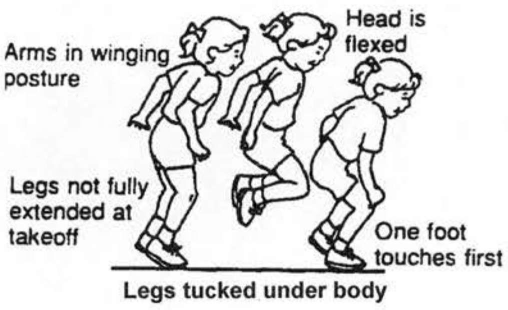
Figure 3. Side view of child wearing belt

Figure 4. Control box of belt.

Figure 3

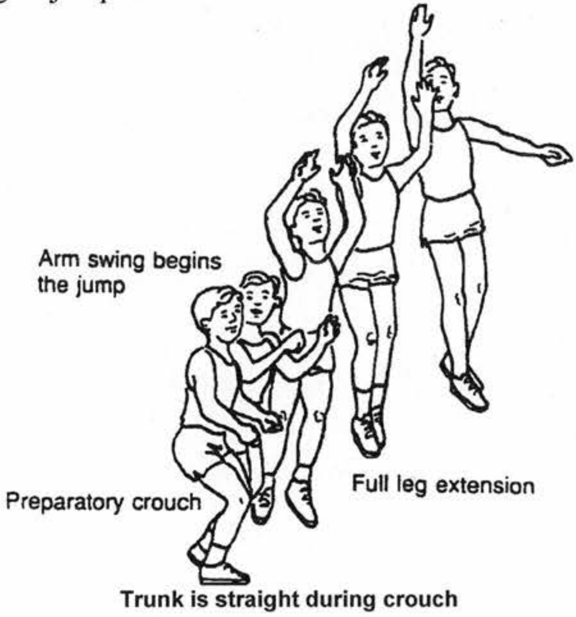
The Sargent Jump

A beginning Sargent jumper.



The form here is inefficient. The legs are tucked up under the body rather than fully extended to project the body off the ground. Notice that one foot touches down first. The arms do not assist the jump. The jumper holds them in the winging posture.

An advanced Sargent jumper

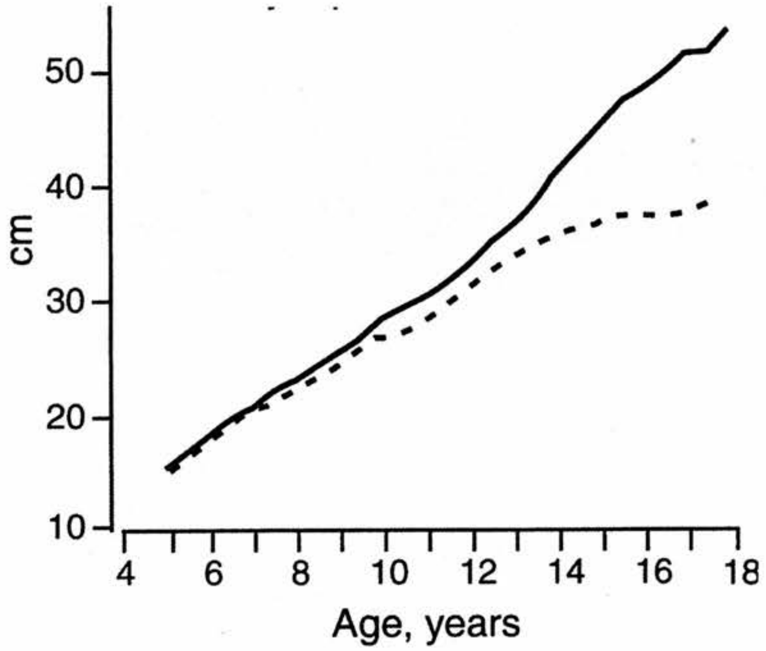


From a preparatory crouch, this basketball player swings his arms forward and up to lead the jump. The hips, knees, and ankles extend completely at takeoff. Near the peak of the jump, one hand continues up while the other comes down, tilting the shoulder girdle to assist the high reach. Note that the trunk tends to remain upright throughout.

(Haywood & Getchell, 2001, p.132)

Figure 4

Mean performance in the Sargent jump between 5 and 18 years of age.



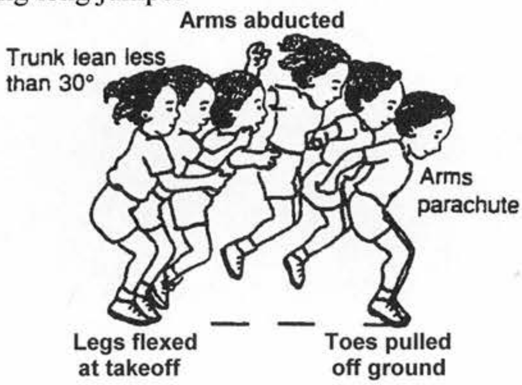
Data from Motor Performance Study of Michigan State University, by permission of J.L. Haubenstricker.

(Malina, Bouchard & Bar-Or, 2004, p.221)

Figure 5

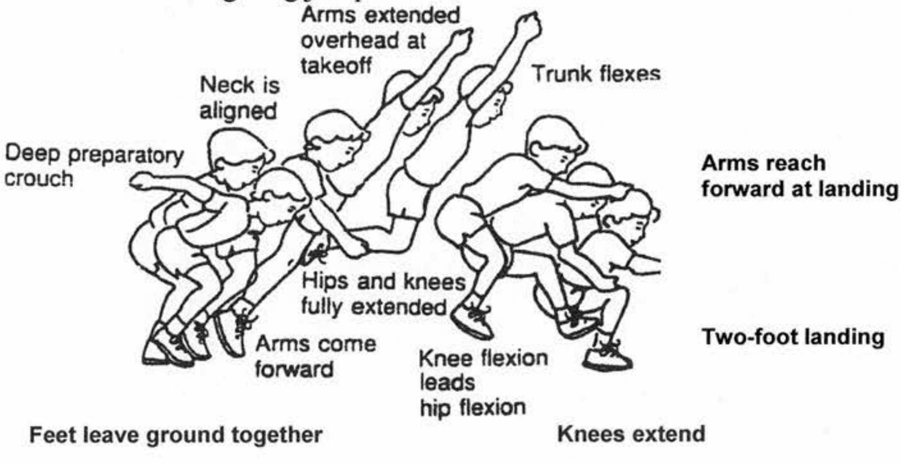
Standing Long Jump

A beginning standing long jumper



As the jumper's weight shifts forward, the toes are pulled off the floor to "catch" the body at landing. The trunk lean at takeoff is less than 30 degrees from the vertical. The arms are used at takeoff but are in an abducted position, laterally rotate in flight, and "parachute" for the landing.
Drawn from film tracings from the Motor Development and Child Study Laboratory, University of Wisconsin-Madison.

An advanced standing long jumper.

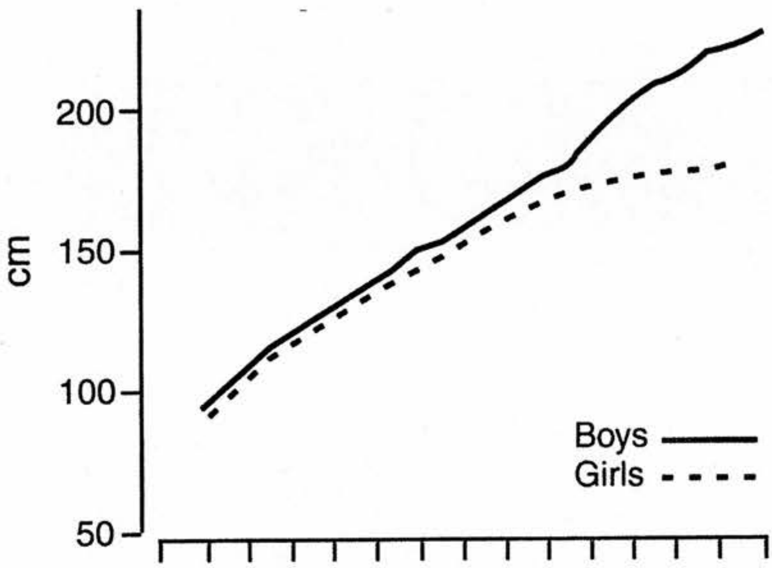


The feet leave the ground together and touch down together. The legs fully extend at takeoff, beginning with heels up. The knees then flex in flight, followed by hip flexion and finally knee extension to reach forward for landing. The trunk is inclined more than 30 degrees at takeoff, and the jumper maintains this lean in flight until the trunk flexes for landing. The arms lead the jump and reach overhead at takeoff. They then lower to reach forward at landing.

(Haywood & Getchell, 2001, p.132)

Figure 6

Mean performance in the standing long jump between 5 and 18 years of age.



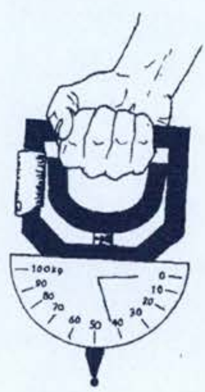
Data from Motor Performance Study of Michigan State University, by permission of J.L. Haubenstricker.

(Malina, Bouchard & Bar-Or, 2004, .221)

Figure 7

The Strength and Power Tests

Grip Dynamometer Test

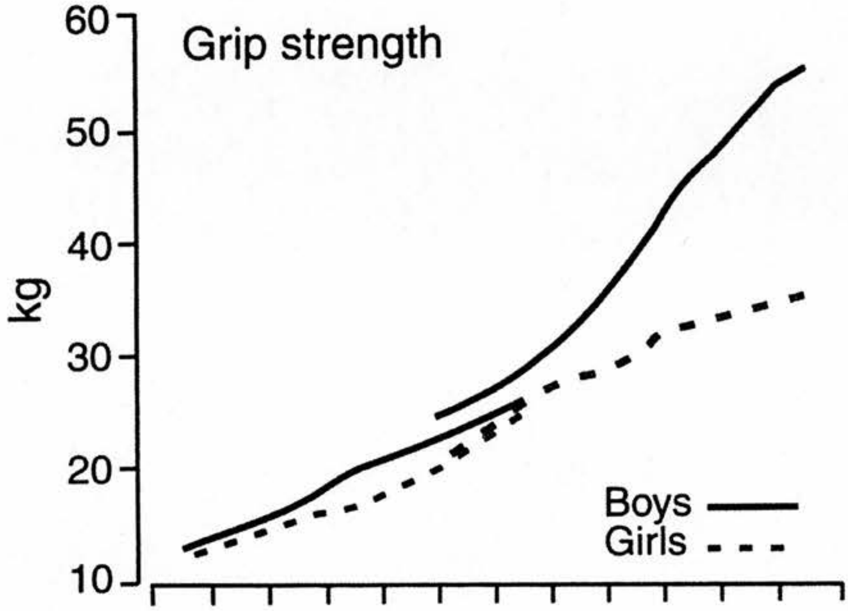


1. Adjust the dynamometer to a position that is comfortable to fit the subject's hand size.
2. Have the individual stand erect with the arms extended at the side and squeeze the dynamometer with maximal effort without moving the arm.
3. Administer several trials for each hand, with a 1-min rest between trials.

(Howley & Franks, 2007, p.241)

Figure 8

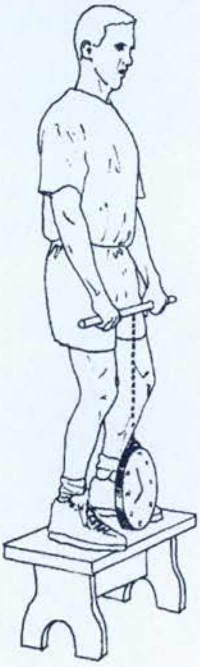
Mean performance in the grip dynamometer between 6 and 18 years of age



(Malina, Bouchard & Bar-Or, 2004, p.219)

Figure 9

Leg and Back Dynamometer Test

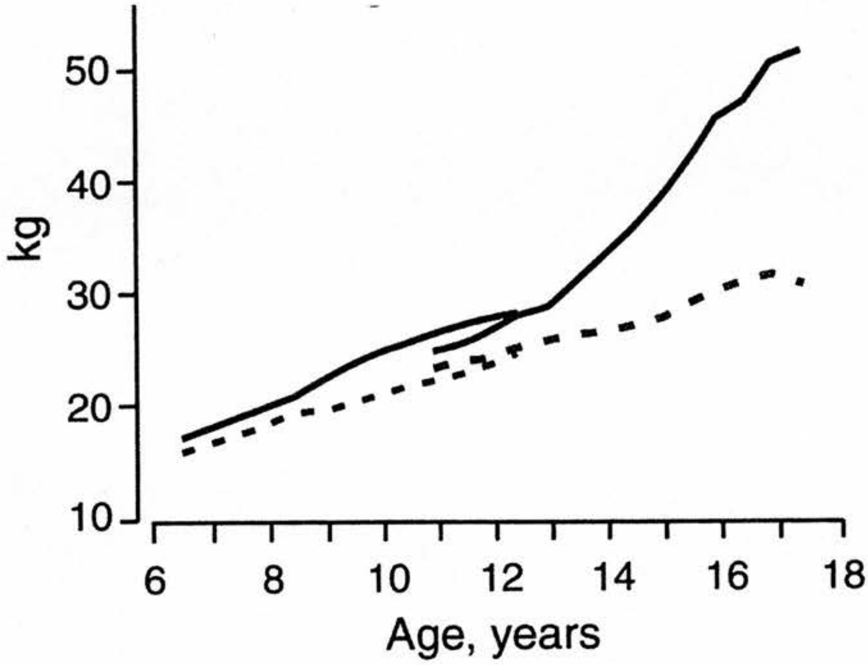


1. Have the subject stand with the trunk erect and the knees flexed to an angle of 130 to 140°.
2. Make sure the subject holds the handbar using a pronated grip.
3. Without using the back, the subject slowly ex-tends the legs with a maximal muscle contraction.
4. Complete 2 to 3 trials with a 1-min rest interval between trials (8).

(Howley & Franks, 2007, p.242)

Figure 10

Mean performance in leg and back dynamometer between 6 and 18 years of age



(Malina, Bouchard & Bar-Or, 2004, p.219)

Figure 11

Sargent Jump Test

History

The Sargent Jump Test, also known as the vertical jump test, was developed by Dr. Dudley Allen Sargent (1849-1924).

Objective

To monitor the development of the athlete's elastic leg strength.

Figure 12

Triple Jump

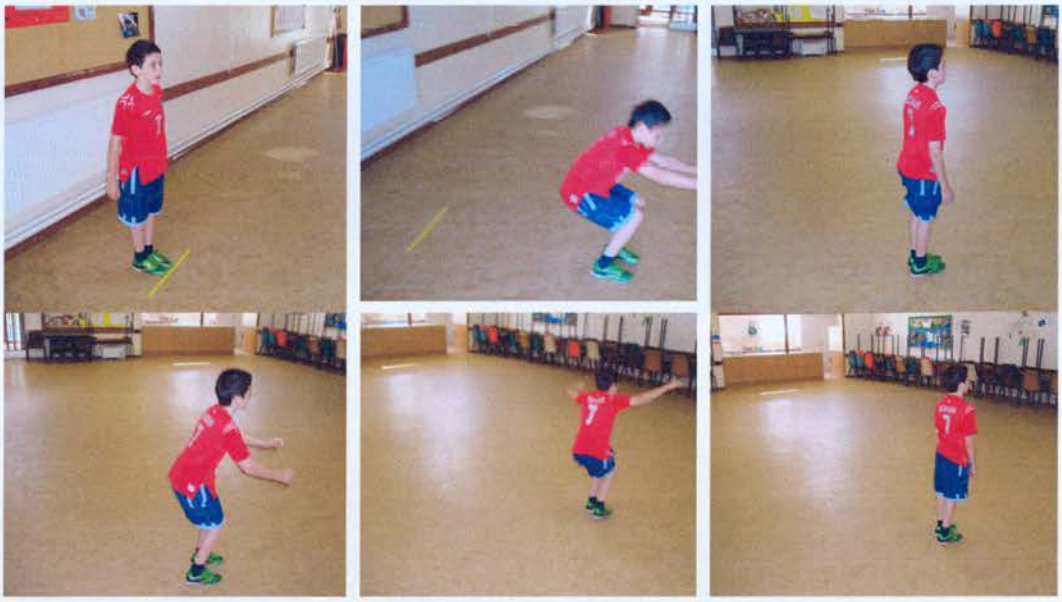
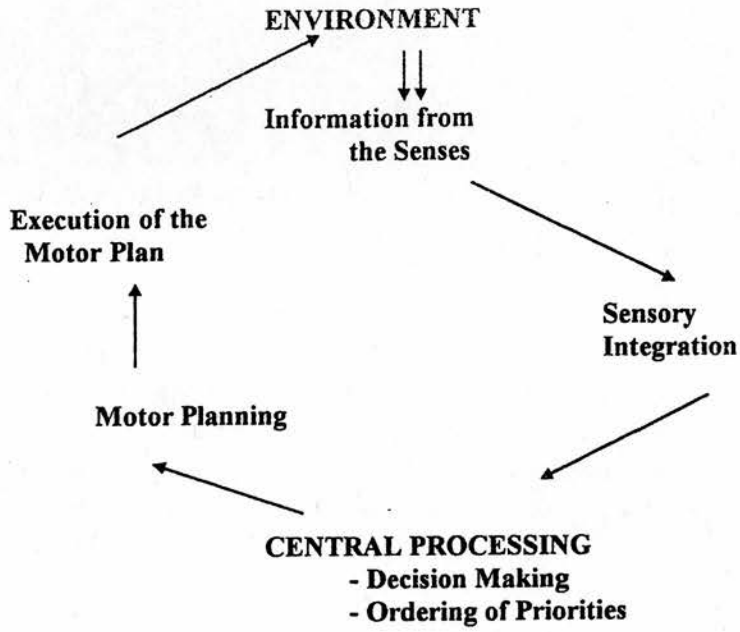


Figure 13

The "feedback loop" for efficient praxis.

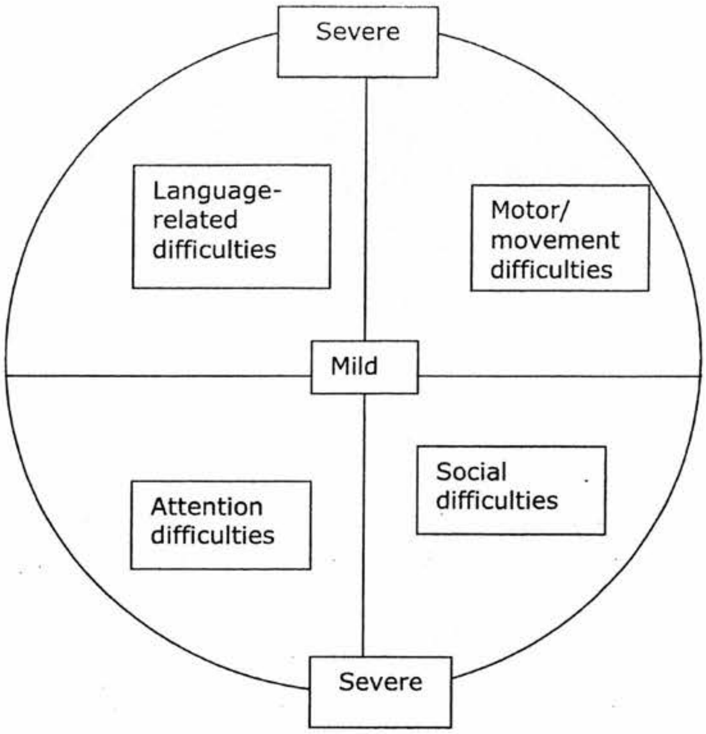


(Ripley, Daines & Barrett, 1997, p.6)

Figure 14

Specific Learning Difficulties: the spectrum

Developmental Coordination Disorder (D.C.D.) continuum of difficulties



Developmental Coordination Disorder (D.C.D.) continuum of needs

Figure 15

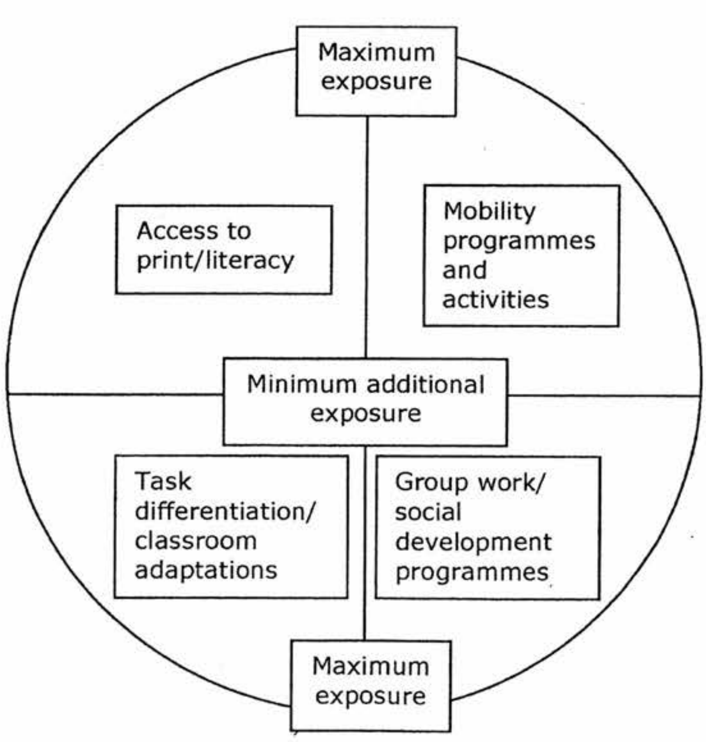
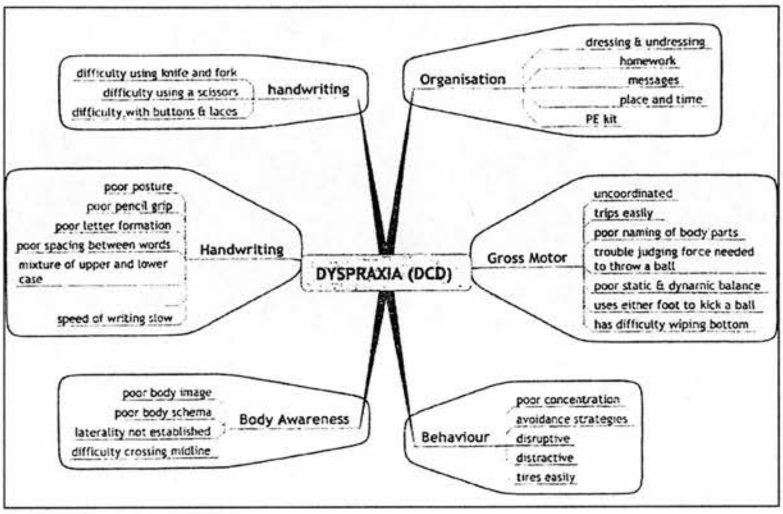


Figure 16

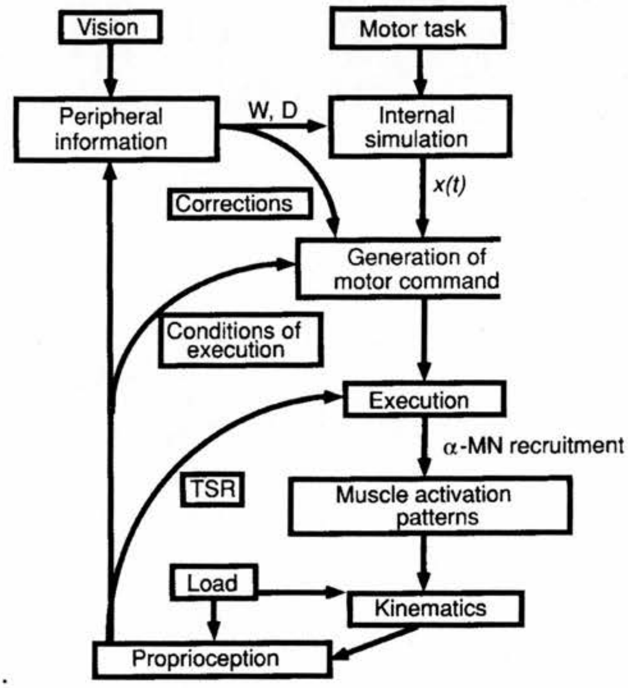
An outline of children's main difficulties in the educational environment.



(Jones 2005, p.4)

A general scheme of production of voluntary movement.

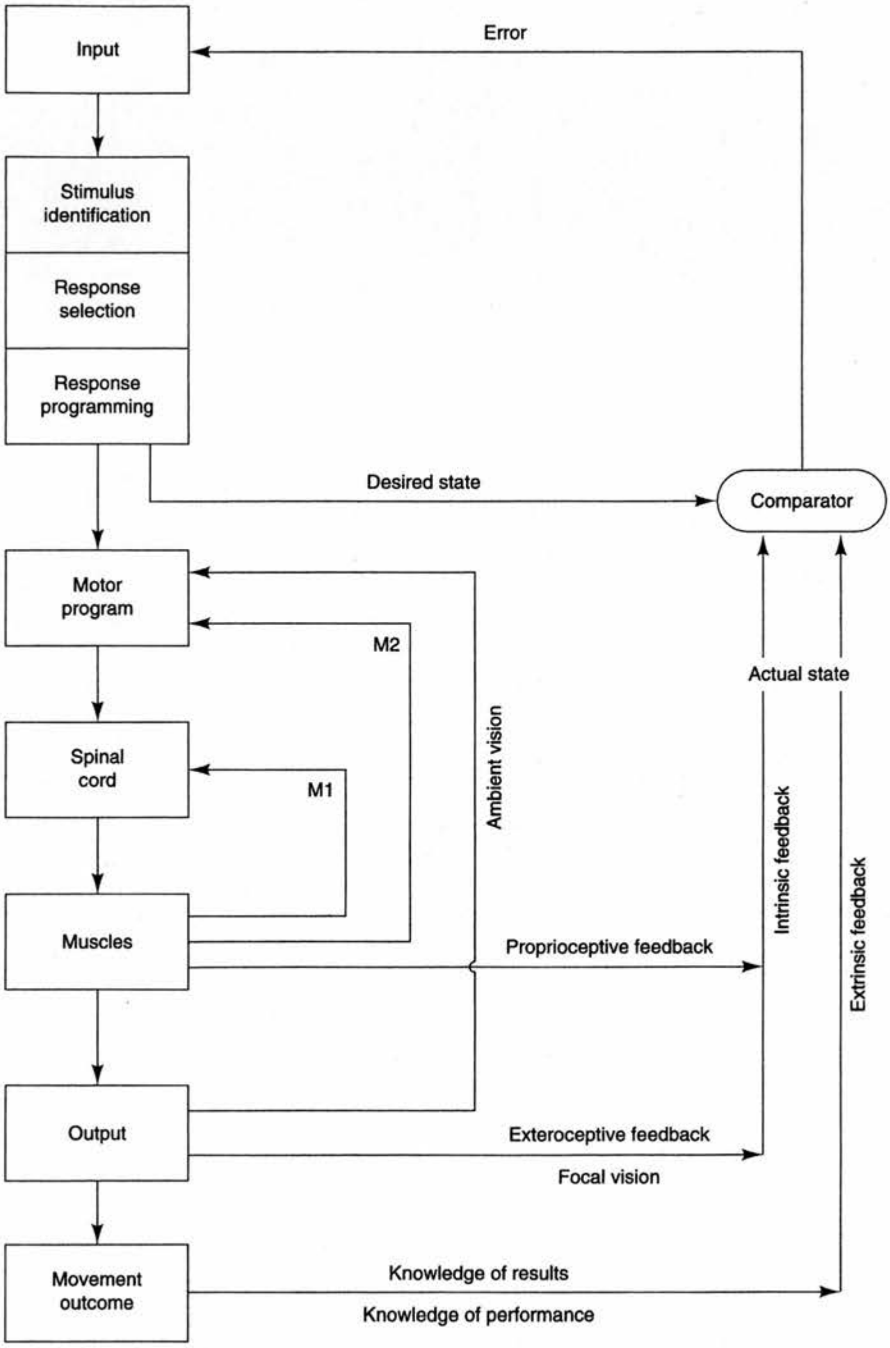
Three major steps include internal stimulation, generation of motor command, and execution.



(Latash 1993, p.180)

Figure 18

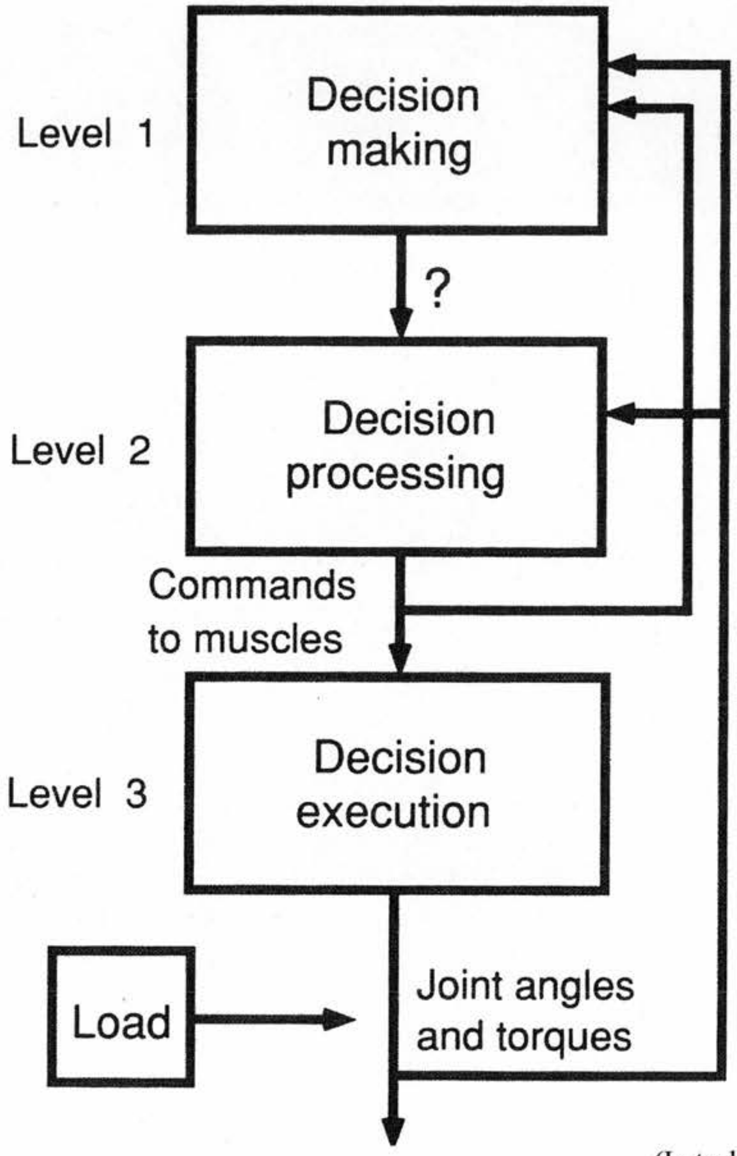
The completed conceptual model of human performance, which is used here as a basis for the organisation of effective practice



(Schmidt & Wrisberg, 2000, p.291)

Figure 19

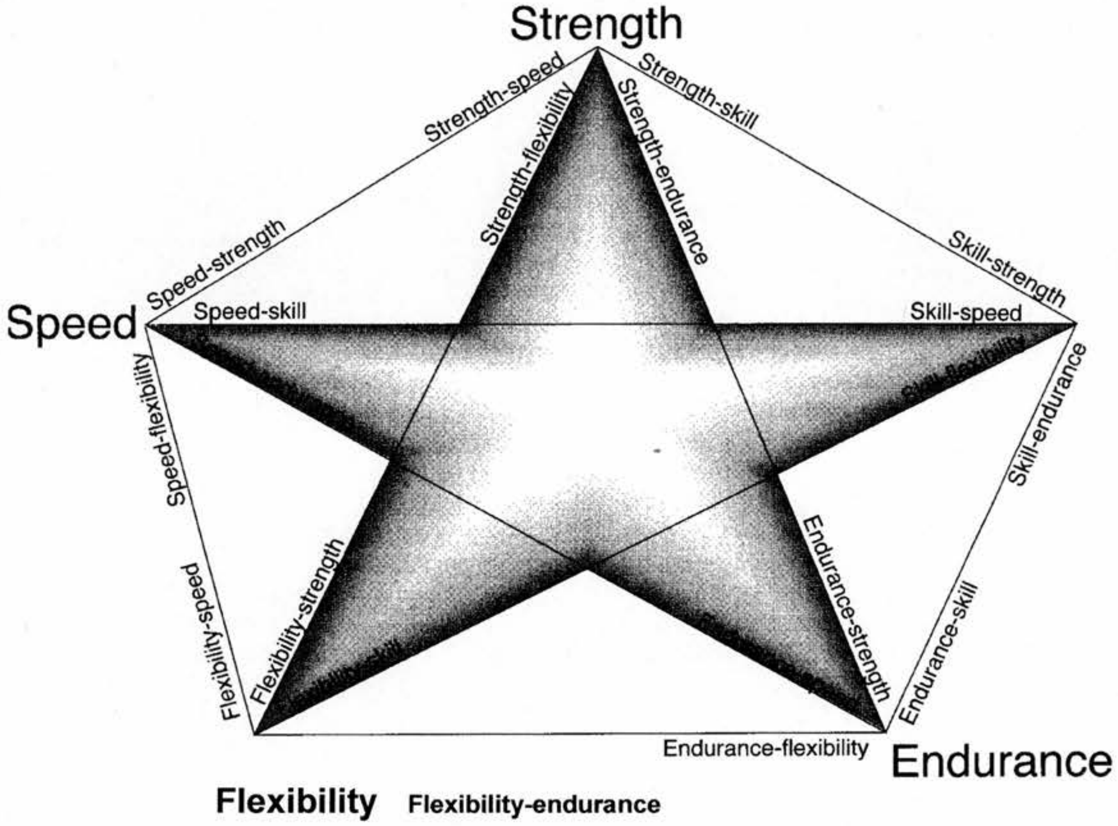
This tentative scheme of voluntary motor control includes three major levels of decision making, decision processing, and decision execution. Note feedback loops connecting all three levels. We will be mostly interested in the functioning of the decision-processing level (Level 2)



(Latash 1993, p.4)

Figure 20

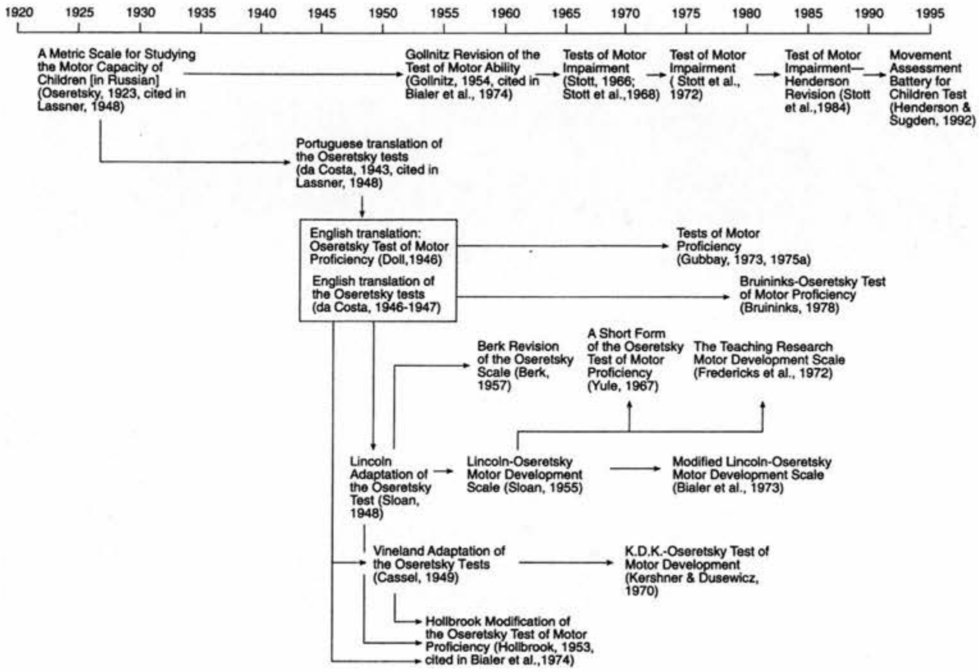
The relationship between the components of fitness



(Stone, Stone & Sands 2007, p.4)

Figure 21

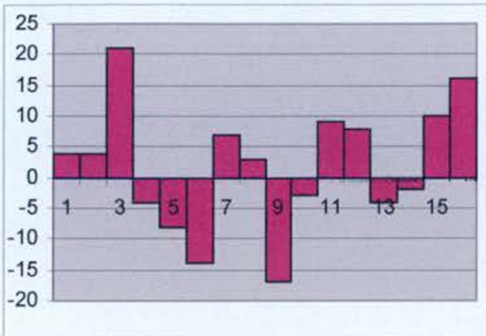
Family tree of motor tests derived from the Oseretsky tests



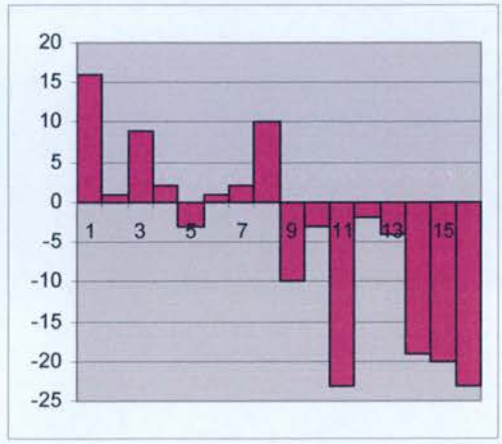
(Burton & Miller,1998, p.29)

Relative rate of growth of body parts (from Harre 1986) **Figure 22**

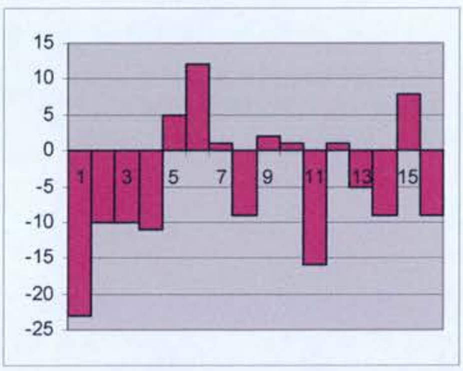
8-9 Years



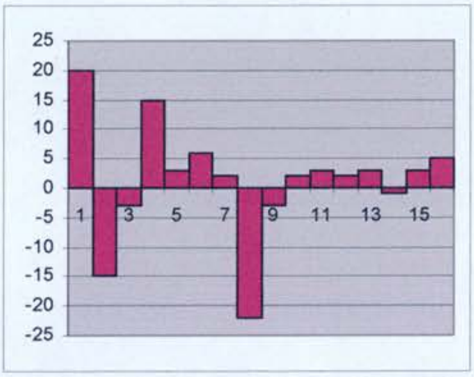
11-12 Years



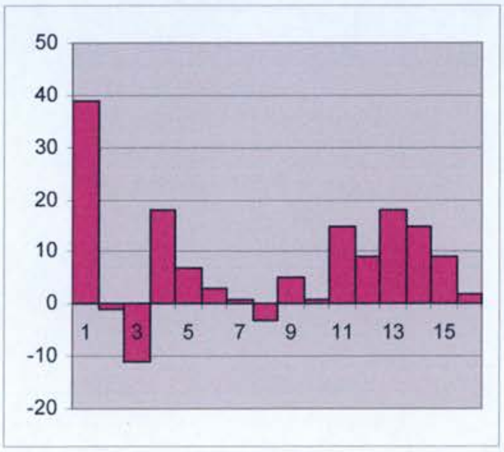
9-10 Years



12-13 Years



10-11 Years



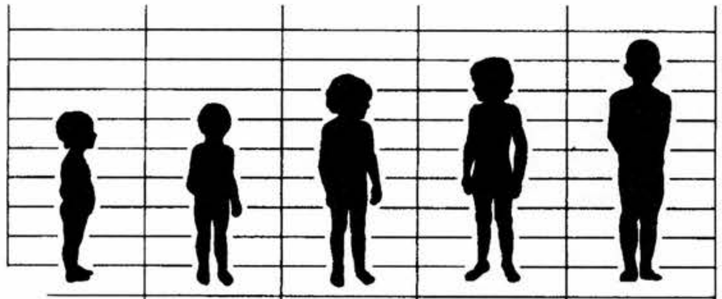
Key

Body weight
Body height
Length of upper arm
Length of lower arm
Length of thigh
Length of lower leg
Span
Shoulder width
Pelvic width
Chest diameter (transverse)
Chest diameter (sagital)
Chest circumference (mean)
Upper arm circumference
Lower arm circumference
Thigh circumference
Lower leg circumference

(Dick 2003, p.34)

Table 1

Growth of the child



Height	Height	Height	Height	Height
Boys 0.94-0.97	Boys 1.01-1.05	Boys 1.07-1.12	Boys 1.15-1.22	Boys 1.25-1.31
Girls 0.92-0.95	Girls 1.00-1.03	Girls 1.06-1.11	Girls 1.15-1.21	Girls 1.24-1.31

GIRLS				
Height	Height	Height	Height	Height
1.25-1.35	1.34-1.48	1.48-1.62	1.56-1.65	1.60-1.68

Fig. 10 Growth of the child. Average height progression, showing the 'parting of the ways' after approximately 9 years, in terms of relative height increase, and absolute height.

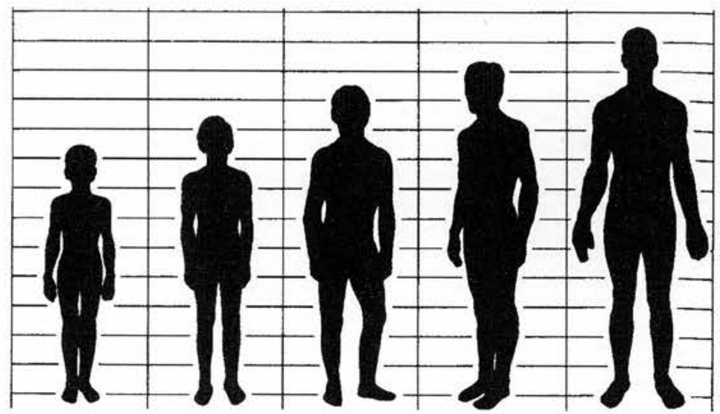
Modified from Family Health Guide (Reader's Digest, 1972)

(Dick, 2003, p.29)

Table 2

Growth of the child (2)

9-10 yrs	11-12yrs	13-14yrs	15-16yrs	17-18yrs



BOYS				
Height	Height	Height	Height	Height
1.25-1.37	1.36-1.48	1.47-1.61	1.59-1.74	1.66-1.81

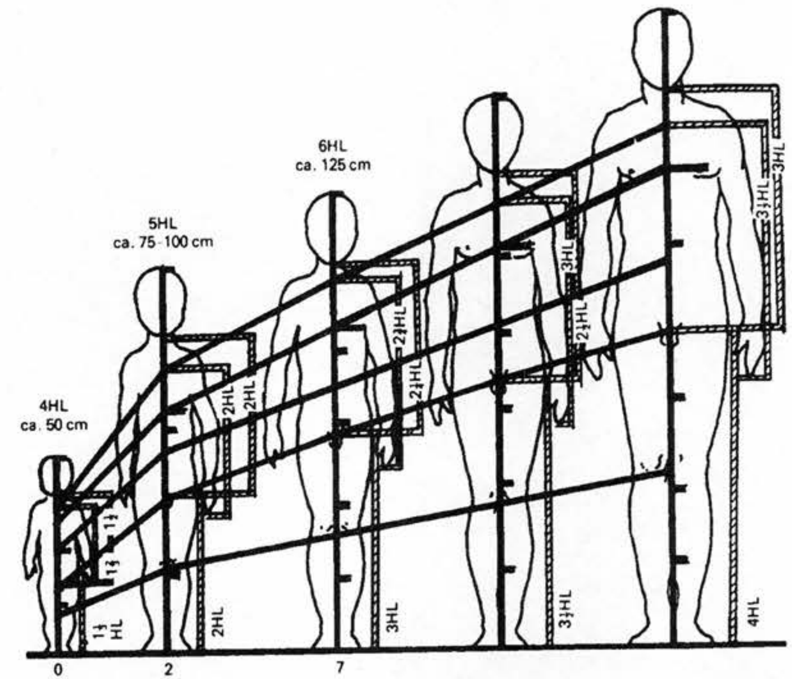


Fig. 11 Alterations in body proportions during growth (from Bammes, 1964)

(Dick, 2003, p.29)

Table 3

Milestones of typical development

Age	Fine motor	Gross motor	Speech language	Cognitive/perceptual	Perceptual/ social
3 months	Hands remain open during rest	Head lags behind when pulled to sitting from lying on back	Coos/smiles in response to pleasant tones Laughs aloud Searches for sound with eyes	When lying on back, promptly looks at toy and follows with eyes	Shows anticipation of bottle/food through facial response
6 months	Passes toy from hand to hand when lying on back Rakes at tiny object using all fingers	Plays with feet while lying on back Rolls in both directions Sits with hands propped forward Stands and bounces when held by both hands	Pays attention to music or singing Understands "hi" and "bye-bye" Imitates familiar sounds, babbles (e.g. "wawa," "baba")	Shakes rattle on purpose	Holds own bottle Drinks from cup that is held by adult Mouths/ gums hard cookie or cracker
9 months	Grasps block with fingers, not palm of hand Wrist is extended (bent back) during grasp of block	Head leads when pulled to sitting from lying on back Creeps or crawls on all fours Sits independently with hands free for play Pulls to stand at low table	Stops activity when name is called Understands "no" Uses some gesture language Participates in "pat-a-cake," "peek-a-boo"	Holds one block or toy in each hand and bangs together at midline	Feeds self cracker Finger feeds small bits of food (like cereal or cut-up vegetables)
12 months	Builds tower of two blocks Uses mature pinch grasp (thumb and tip of forefinger)	Stands alone without support Takes first steps	Responds to simple commands without any gestures Knows one body part Beginning to use single	Imitates scribbling with crayon	Brings pre-filled spoon to mouth, but spills Holds handle of cup while drinking

	Holds crayon using fisted grasp Helps to turn pages in a book		words meaningfully		Holds out arms and legs for dressing
15 months	Builds tower of three blocks Can place small pegs in pegboard	Crawling is discarded except on stairs Plays while squatting Gets to standing position without holding on to anything	Points to object when named Points to several body parts	Fills container with blocks Scribbles with crayon without demonstration	Shows awareness/ discomfort when diaper is soiled Scoops food with spoon (spills)
18 months	Builds tower of four blocks Turns pages of book, two or three at a time	Seats self in small chair Climbs stairs holding rail	Refers to self by name Puts together two-word sentences	Inserts simple shapes into a formboard	Removes socks Sometimes indicates the need to eliminate before an accident Chews semi-solid food
24 months	Builds tower of seven blocks Strings small beads	Kicks a ball forward Jumps with both feet leaving floor	Produces 25-200 words Jargon has disappeared Points to pictures in book Enjoys listening to simple stories and nursery rhymes	Matches three colours Imitates strokes (circular scribble, straight vertical line) with crayon	Holds glass with two hands Has bladder control Imitates housework Drinks from straw Recognises/ edible/ nonedible food Helps pull down pants Finds armholes to pullover shirt
30 months	Builds tower of nine blocks Turns pages of	Climbs stairs with one foot to each step Stands on one foot briefly	Understands taking turns	Imitates circle, horizontal stroke with	Uses napkin Unfastens large buttons

	book one at a time Shows preference for one hand	Rides tricycle		crayon Names own drawings, even if unrecognizable	Puts away jacket/ toys Assists in pulling on socks
36 months	Builds tower of ten blocks Holds crayon with fingers like adult Cuts "fringe" with scissors	Runs on toes Runs, turning sharp corners without falling Performs broad jump about 12 inches distance	Vocabulary of about 1000 words Carries on purposeful conversation No longer repeats or echoes others	Imitates cross with crayon Names and sorts objects by colour Counts three objects correctly	Feeds self with fork, spoon, rarely spilling Zips and unzips zipper once engaged Snaps front snaps Buttons large buttons Puts on shoes, wrong foot Turns water on/off
42 months	Can place ten pellets or raisins in small bottle within 25 seconds Shifts crayon up/ down in fingers to adjust	Stands on tiptoe for ten seconds Hops on one foot		Names some letters and numbers	Puts shoes on correct feet Knows front from back of clothing Puts on mittens Can undo buckle Blows nose into tissue
4 years	Can place ten pellets or raisins in small bottle within 20 seconds Cuts 1-inch wide line within half inch	Performs somersault Catches a beanbag with the hands (not against body) Performs broad jump about 24 inches distance	Can recall four digits in sequence Speech is 90% understandable	Copies square with crayon Draws one or two letters, numbers	Removes pullover garment Puts socks on correctly Washes/ dries face/hands effectively Runs brush/ comb through hair

					Places dirty clothes in hamper Sets table with help
5 years	Can place ten pellets or raisins in small bottle within 10 seconds Cuts out square within quarter inch	Runs through obstacle course avoiding obstacles Skips with alternating swing Stands on one foot for 10 seconds		Counts ten objects correctly Prints first name Draws recognizable face with eyes, nose, mouth	Drinks from water fountain without help Serves self and carries tray in line Wipes self after toileting Dresses without supervision Ties the half knot on shoes Looks both ways to cross street Bathes/ showers when reminded
6 years	Can move coin from palm of band to fingers to place in soda machine	Performs one each of sit-up and knee push-up Rides two-wheeler	Likes silly stories and riddles	Copies triangle and crude diamond Prints all letters and numbers one to nine without a model to copy Prints last name Performs simple addition and subtraction	Uses knife/ fork to eat Ties bow Closes fastener on back of clothes Cares for nose effectively Initiates phone calls to others Fastens back buttons Adjusts faucet temperature for bath

				Discriminates left from right	
7 years			Reading and writing at school	Prints three to-four word sentences Reversals in writing are no longer common	Styles hair Knows value of coins
8 years					Bathes/ showers independently Remembers to wash ears Sweeps, mops or vacuums floors
10 years				Writes in cursive instead of printing	Ties necktie Uses stove or microwave independently Uses household cleaning agents appropriately Uses deodorant
12 years					Counts change for purchases costing more than £1.

(Kurtz, 2008, pp.18-22)

Table 4

Behavioural Indicators of Developmental Dyspraxia

The following descriptions indicate a child who may have Developmental Dyspraxia. It is important to note that some children may have a mixture of different conditions, e.g. dyspraxia, dyslexia, attention deficit disorder, etc.

MOTOR DEVELOPMENT

Gross Motor Skills	Fine Motor Skills	Motor Organisation
▪ Awkward running, climbing ▪ Awkward balance ▪ Difficulty hopping, skipping ▪ Easily fatigued ▪ Difficulty catching or hitting a ball ▪ Difficulty riding a bike ▪ Difficulty with P.E.	▪ Awkward holding pencil, crayon ▪ Difficulty cutting, pasting, colouring ▪ Difficulty handwriting ▪ Difficulty using a knife and fork ▪ Difficulty tying shoe laces	▪ Lacks smoothness in clapping, tapping ▪ Reacts slowly or quickly to moving stimuli ▪ Difficulty in sequencing ▪ Difficulty with laterality ▪ Difficulty with spatial orientation and directionality.

PERCEPTUAL DEVELOPMENT

Visual Perception	Auditory Perception	Perceptual-Motor Skills
▪ Difficulty matching shapes, sizes ▪ Difficulty discriminating differences – colour, form, shape, size ▪ Difficulty recognising what is missing ▪ Confusion of foreground and background ▪ Difficulty recalling what is seen ▪ Difficulty distinguishing between b and d. 6 and 9. 21 and 12. etc.	▪ Does not understand what is heard ▪ Cannot carry out directions ▪ Cannot identify sounds ▪ Difficulty recalling a sequence of sounds ▪ Difficulty responding to verbal directions	▪ Poor knowledge of body parts ▪ Difficulty assembling puzzles ▪ Difficulty copying or tracing ▪ Reverse letters. Words ▪ Poor spacing of drawing or writing ▪ Difficulty staying on line or within boundaries on paper ▪ Does not follow directions ▪ Difficulty learning to dress

ATTENTION AND ACTIVITY LEVEL

Distractibility	**Hyperactivity**	**Hypoactivity**
▪ Difficulty screening out irrelevant stimuli ▪ Difficulty focusing on tasks	▪ Restless activity ▪ Inability to sit still ▪ Always up - down. squirming	▪ Lethargic, listless ▪ Lacks interest or motivation to learn ▪ Withdrawn

BEHAVIOURAL TRAITS

Perseveration	**Disinhibition**	**Impulsivity**
▪ Repeats words and actions excessively ▪ Difficulty shifting from one activity to another	▪ Little regard for danger ▪ Grabs. puts hands where they don't belong ▪ Has to be first	▪ Sudden inclination to act without thought ▪ Overly bold and aggressive ▪ Can't wait. runs out of line

LANGUAGE DEVELOPMENT	PERSONALITY DEVELOPMENT	ACADEMIC LEARNING
▪ Difficulty understanding meaning of words ▪ Difficulty in grammatical structure ▪ Difficulty reproducing sequence of words presented ▪ Difficulty expressing thoughts ▪ Difficulty in blending separate parts of a word	▪ Daydreams ▪ Difficulty being accepted by peers ▪ Insecurity - need for constant approval or reassurance ▪ Nervous traits - pencil chewing, nail biting. thumb sucking ▪ Exaggerated emotional responses ▪ Unhappiness. cries easily	▪ Difficulty learning concepts ▪ Difficulty learning symbols – numbers, letters etc. ▪ Difficulty handwriting ▪ Difficulty learning to read ▪ Difficulty in spelling ▪ Difficulty in mathematics

(Chu, 1995, p.5)

Table 5

Professionals involved in evaluation of children with developmental motor concerns

Professional	Typical services provided	Qualifications	When referral is indicated
Audiologist	Perform hearing tests Obtain hearing aids or other devices	Master's degree Clinical fellowship year (CFY) National certification exam	Delayed speech or language Parent concerns about hearing Recurrent ear infections
Developmental or behavioral optometrist	Assess eye health, acuity, and functional vision skills Provide interventions that may include vision therapy to address problems with visual efficiency.	Completion of a four-year graduate program leading to a Doctor of Optometry (OD) Completion of postgraduate examination by one of two organizations: 1. American Academy of Optometry or 2. College of Optometrists in Vision Development	Physical signs of eyestrain Poor reading comprehension despite good vocabulary and speech Blurred or double vision Frequently losing place during reading Avoidance of visual activities
Developmental paediatrician	Diagnosis and medical management of developmental delay	Board certified pediatrician Three-year fellowship in developmental pediatrics	Suspected developmental disorder Conflict of opinion regarding diagnosis or management of developmental concerns
Geneticist	Testing to determine presence of inherited diseases	Medical degree Fellowship and board certification in genetics	Congenital malformations or stigmata Family history of mental retardation, genetic disease, chromosome abnormality, known or suspected syndrome

Neurologist (paediatric)	Evaluation and management of nervous system disorders	Medical degree Residency in pediatric neurology Board certification	Loss or plateau of developmental skill Known or suspected seizures Unknown etiology of developmental disability
Occupational therapist	Evaluation and management of problems performing daily living skills	Occupational therapist: BS or MS in occupational therapy Board certification Licensure (varies by state) Advanced pediatric certification available for pediatrics, sensory integration, or neurodevelopmental therapy OT assistant (OTA): AS in occupational therapy Board certification Licensure (varies by state) Must be supervised by occupational therapist	Limited ability to succeed in daily activities Limited mobility, especially fine motor Poorer nonverbal than verbal development Frustration leading to task avoidance, poor attention, or problems with social interactions
Physical therapist	Evaluation and management of problems with mobility	Physical therapist: BS or MS in physical therapy Board certification Licensure (varies by state) Advanced pediatric certification available for pediatrics, sensory integration, or neurodevelopmental therapy	Delayed gross motor development or abnormal movement quality

		PT assistant (PTA): AS in physical therapy Board certification Licensure (varies by state) Must be supervised by physical therapist	
Psychiatrist	Evaluation and management of emotional disorders	Medical degree Residency (pediatrics, internal medicine, and/ or psychiatry) Board certification	Suspected impairment in emotions or thought processes Serious behavioral or adjustment problems
Psychologist	Evaluation of cognitive capabilities and potential Measurement of academic achievement and educational needs Evaluation and management of problematic behavior	Psychologist: Doctoral degree in psychology Internship and fellowship (varies by state) State licensure School psychologist: Master's degree in psychology Supervised field experience State licensure National certification exam (NCSP)	Undiagnosed development delay Decline/ regression in skill development School performance poorer than expected Inappropriate or atypical behavior

Social Worker	Provide support to child and family around social and emotional adjustment Assist family to identify and access community services or entitlements	Master's degree in social work Licensure (some states) Advanced certification available (ACSW)	Suspected child abuse or neglect Acute distress in child or family Chronic stress related to care giving responsibilities Poor parental adjustment to diagnosis Assistance needed for referral, access, or funding for services
	Design and implementation of specialized programs of educational instruction	Minimum requirements: Bachelor's degree in education One semester supervised student teaching Certifications (e.g. early childhood, reading specialist): Varies by state	Child meets eligibility requirements as' defined by state for early intervention or special education
Speech language pathologist	Evaluation and management of problems with communication	Master's degree in speech/language pathology Clinical fellowship year (CFY) National certification exam Licensure (some states)	Delay or impairment in communication skills Problems with oral-motor coordination affecting speech

(Kurtz, 2008, p.xxx)

Table 6

Tests for Movement Difficulties

Test of motor coordination and skill	References	Age (years; months)	Normative samples	Duration of testing	Reliability
The Lincoln-Oseretsky Motor Development Scale	Sloan, 1955 Roge, 1984	5;6 to 14;6	• United States • France	30-45 minutes	test- retest
Bruininks-Oseretsky Test of Motor Proficiency	Bruininks, 1978	4;6 to 14;6	• United States	45-60 minutes 15-20 minutes	test- retest
Movement ABC	Henderson & Sugden, 1992 Soppelsa & Albaret, 2004 Smits-Engelsman et al., 1998	4 to 12	• United States • France • The Netherlands	25-30 minutes	test-retest
The Charlop-Atwell Scale for Motor Coordination	Charlop & Atwell, 1980 Albaret & Noack, 1994	3;5 to 6	• United States • France	15 minutes	test-retest inter-observer
Test of Gross Motor Development	Ulrich, 1985,2000	3 to 10	• United States	15-20 minutes	test-retest inter-observer
Purdue Pegboard test	Tiffin, 1968 Beguet & Albaret, 1998	6 to 10	• United States • France	15 minutes	test-retest inter-observer
Concise Evaluation Scale For Children's Handwriting-BHK	Hamstra-Bietz et al., 1987 Charles et al., 2003	6 to 11	• France • The Netherlands	5 minutes	inter-observer intra-observer

Gestural and constructional praxis					
Gesture imitation test	Berges & Lezine, 1963 Vaivre-Douret, 1997	3 to 12	• France	10 minutes	test-retest inter-observer
Rey's Complex Figure test	Rey, 1959 Corwin & Bylsma, 1993	4 to adult	- Canada - United States - France		test-retest inter-observer
Beery-Buktenica Developmental Test of Visual-Motor Integration	Beery & Buktenica, 1997 Beery et al., 2003	2 to 8	- United States	10-15 minutes	test-retest homogeneity
Stick test	Butters & Barton, 1970 Albaret & Couderc, 2003	6;6 to 11;5	- France	20 minutes	test-retest inter-observer homogeneity
Perceptuo-motor skill					
Development Test of Visual Perception	Frostig, 1973 Hamill et al., 1993	4 to 7	- United States - France	35 minutes	test-test inter-observer homogeneity
Sensory Integration and Praxis Tests	Ayres, 1989	4 to 8;11	- Canada - United States	90-120 minutes	test-retest inter-observer'
Kinaesthetic Sensitivity Test	Laszlo & Bairstow, 1985	5 to 12, adults	- Great Britain -Australia -Canada		
Kinaesthetic Acuity Test	Livesey & Coleman, 1998	3 to 5	-Australia		test-retest

Table 7

Studies reporting significant overlap of additional diagnoses with DCD/ motor impairment

Reference	Motor impairment	Number of children/ age	Emotional	Conduct	Attention deficit/ hyperactivity	Social	Reading/ scholastic	Speech/language impairment
Cantell, Smyth and Ahonen, 1994	Identified at age 5 with motor delay	106 DCD equivalent and 40 controls Age 15				Clumsy children fewer hobbies and reduced social/ physical activities	Reduced academic ambitions	
Cermak et al., 1986	Movement ABC/TOMI	5-8 years						40% children with SLI met criteria for DCD
Gillberg and Gillberg, 1989	MBD perceptual motor criteria	Population cohort 42 children with DAMP 13 years	75% children with motor difficulties had experienced school failure or were identified with emotional and/or behavioural problems					
Gillberg, Gillberg and Groth, 1989	MBD perceptual motor criteria	Population cohort 42 children with DAMP 13 years			49% children with motor difficulties met criteria for ADHD			

Fletcher-Flinn, Elmes and Stragnell 1997	TOMI	28 DCD 7.5-9.7 years					68% reading problems 25% >2years below; 93% spelling problems 30% > 2 years below; Most children scored poorly on phonological processing	
Green et al., 2002	Movement ABC	9 SDDMF 11AS 7-10 years				Similarities between SDDMF & AS children		
Green, Baird and Sugden, submitted	Movement ABC	47 DCD children 5-11 years	70% emotiona l symptom s	38% conduct problems	68% attention/activity problems	51% peer problems		
Hellgren et al., 1994	Motor-perceptual criteria	45 DAMP 16 year	40% Axis I	15.5% substance abuse 4% suicide attempt	58% Axis II inc. AS			
Hill 1998 Hill et al., 1998	Movement ABC	11 DCD 19 SLI 5-13 years						60% children with SLI met criteria for DCD
Kadesjo and Gillberg, 1999b	Met criteria for DSM-IV	Population study with 55 DCD 6.8 – 7.8 years			47% had symptoms; 19% met diagnostic criteria for ADHD	7% diagnosed with Asperger's Syndrome		

Kaplan et al., 1998	BOTMP or Movement ABC	379 school aged 81/379 DCD 8-18 years			41%* ADHD with DCD * 28%ADHD and reading problems with DCD		55% * reading problems with DCD	
Landgren et al., 1996	Criteria for motor perceptual deficit defined	Birth cohort 6-7 years 63/589 children with MBD			49% ADHD with DCD (DAMP)			
Losse et al., 1991	TOMI	34 motor impaired 15.1-17.4 yrs	82% reported to have conduct and Attentional/ concentration problems from school records			47% poor social self-concept	71 % academic problems	
O'Hare and Khalid, 2002	TOMI/ Movement ABC	23 DCD 7-10 years					Auditory processing problems associated with reading delay	
Owen and McKinlay, 1997	Motor deficits identified via Pegboard, buttoning, bead threading and graphic tasks	16 SLI 16 controls 4-7 years						SLI children were slower on speed and accuracy tasks and more likely to have mixed hand preference.
Moxley-Haegert and Ladd, 1989	Motor delay identified prior to 4	48 7-8 year olds			Hyperactivity associated with motor delay		Motor delay associated with later	

	years						reduced intelligence	
Pick, Pitcher and Hay, 1999								
Powell and Bishop, 1992	Battery of fine and gross motor tasks	17/34 children with SLI6-12 years						SLI group scored significantly worse on 7/19 motor tasks
Rasmussen and Gillberg, 2000	MBD criteria	15 year follow- up 49 meeting DCD criteria seen age 22 years	60% DCD with ADHD showed poor psycho-social outcome				e	
Rintala et al., 1998	Movement ABC	76 Dev: Language impairment 6-10 years						71% children with SLI met criteria for DCD
Robinson, 1991	TOMI	9-17 years						90% children with SLI met criteria for DCD
Schoemaker and Kalverboer, 1994	TOMI	18 6-9 years	33% STAIC			Self-report of social acceptance poor		
Sigurdsson, van Os and	Criteria for motor	Birth cohort followed up	Childhood motor impairment high risk for anxiety in males.					

Fombonne, 2002	impairment met at 7 years old	at 11 and 16 years						
Skinner and Piek, 2001	Movement ABC and criteria for DCD met	8-10 years (n = 116) DCD = 58 12-14 years (n=102) DCD = 58	Children and adolescents with DCD rated themselves as less able scholastically and athletically with lower scores for physical appearance and self-worth. Anxiety was more prevalent in the adolescent group with DCD (n = 102)					
Sooring-Lunsing et al., 1993	Touwens MND criteria *	Population cohort 170/346 MND				Social difficulties associated with fine motor problems	Coordination difficulties related to school failure	
Wright-Strawderman and Watson, 1992	Learning Disabled, group - motor status not measured	53 students 8--10 years	Increased risk of depression in LD group (35.8% scored in the depressed range on the CDI)					

• MND = minor neurological dysfunction identified according to Touwen (1979) measuring posture (reflexes and responses), coordination; fine manipulation; and presence or absence of choreiform dyskinesia

(Sugden & Chambers, 2005. p.99)

Table 8

The 32 Movement Tasks in the Movement Assessment Battery for Children Test (Henderson & Sugden, 1992). Organised by Age Band and by Task Category

Task category	4-6 yr	7-8 yr	9-10 yr	11-12 yr
Manual dexterity 1	Posting coins	Placing pegs	Shifting pegs-by-row	Turning pegs
Manual dexterity 2	Threading beads	Threading lace	Threading nuts on bolts	Cutting out elephant
Manual dexterity 3	Bicycle trail	Flower trail	Flower trail	Flower trail
Balls skills 1	Catching beanbag	1-hand bounce and catch	2-hand catch	1-hand catch
Balls skills 2	Rolling ball into goal	Throwing beanbag into box	Throwing beanbag into box	Throwing at wall target into box
Static balance	One-leg balance	Stork balance	1-board balance	2-board balance
Dynamic balance 1	Jumping over cord	Jumping in squares	Hopping in squares	Jumping and clapping
Dynamic balance 2	Walking heels raised	Heel-to-toe walking	Ball balance	Walking backwards

(Burton & Miller, 1998, p.173)

Table 9

Summary of the 5 Stage Procedure in the Code of Practice
Stage 1 Initial concern by parent/teacher/other professional-register child. Teacher assesses child and action involves special help in normal class, or move to further stage, or no special education help required. Progress reviewed
Stage 2 Initial concern by teacher/parent/professional or from Stage 1 SENCO registers child and obtains help and information SENCO and teacher draw up IEP and implement it. Review progress with child reverting to stage 1, continuing at 2 or moving to 3.
Stage 3 Initial concern by teacher, parent/professional or from Stage 2 SENCO registers child and a recognition that specialist support is immediately necessary. Consultation with professionals from outside school. IEP drawn up and implemented. Review progress with child reverting to Stage 1 or 2; continue at Stage 3. Headteacher requests statutory assessment.
Stage 4 Referral by child's school following 3 school procedures or from a formal request by a parent. Multidisciplinary formal assessment by education, psychology, health, parental input and other services such as social services.
Stage 5 Statement of special educational need.

Department for Education (1994)

Table 10

Therapies

Type of Therapy	*Description*
Aquatic Therapy	The use of swimming and other pool activities to promote motor skills. Therapy is usually conducted by an occupational or physical therapist. The reduced gravitational pull provided by an aquatic environment, often combined with use of warm water, makes movement easier for some children.
Aromatherapy	The selected use of essential plant oils applied through inhalation, diffusion, or massage used to improve health and well-being. Most oils have stimulating, sedative, regulating, or euphoric effects, and may help to reduce stress and promote regulation among children with autism or other learning disabilities.
Auditory Training	The use of sound stimulation, provided through headphones, designed to improve the child's listening, learning, movement, organization, and self esteem. Method used especially with children with sensory processing difficulties including autism and ADHD. Various programs include Berard Auditory Integration Training (AIT), the Tomatis Method, and the Listening Program.
Brain Gym	A program of physical movements designed to integrate body and mind to improve concentration, memory, reading and writing skills, organization, listening, and physical coordination. The exercises focus on crossing the midline, lengthening activities, and energy exercises.
Craniosacral therapy	A manual therapy approach that focuses on releasing pressure or binding of the membranes and fluid surrounding the brain and spinal cord. Proponents believe this allows for greater flexibility and posture, reduces the effects of stress, enhances health, and improves resistance to disease.
Dance/ movement therapy	The use of movement as a psychotherapeutic process to further the emotional, cognitive, and physical integration of the individual, and for purposes related to disease prevention and health promotion. Therapists complete a Master's degree in dance/ movement therapy, supervised internship, and national registration.
Developmental optometry	The use of special lenses, vision exercises, and other vision training methods to alleviate inadequate visual skills and visual stress. These vision problems may cause a variety of functional problems, including incoordination in sports. Practice of developmental optometry requires postgraduate training beyond that required to practice general optometry.

Interactive Metronome	A three- to five-week computer-driven program that combines a musical metronome with interactive hand and foot exercises that challenge a person's rhythm and timing to improve foundation skills important to learning and development. Improvements are expected in attention, motor control and coordination, language processing, reading and math fluency, and ability to regulate impulsivity.
Myofascial release	A therapeutic treatment using gentle, manual manipulation of fascia, which is a tough connective tissue occurring throughout the body, in order to promote health and improved posture.
Therapeutic brushing (Wilbarger Protocol)	A specific program of brushing the child in order to reduce the effects of sensory defensiveness, which may include over activity, inattentiveness, and emotional volatility. The procedure is based on principles of sensory integration therapy, and has become a popular adjunct to many occupational therapy programs.
Therapeutic massage	The use of various massage techniques to promote physical, emotional and intellectual development of the child, "and to improve bonding and attachment between the child and parent.
Therapeutic riding (hippotherapy)	The use of horse and equine-oriented activities to achieve a variety of therapeutic goals, including cognitive, physical, emotional, social, educational and behavioral goals. Hippotherapy is a specific type of therapeutic riding that is based 011 a medical model, and is practiced by occupational and physical therapists who have special training in this method.
Yoga	Yoga uses an integrated series of balanced poses to increase body awareness, strength, and flexibility. These are combined with specialized breathing exercises and relaxation techniques that may improve concentration and reduce hyperactivity.

In deciding which approach they will use, therapists must consider a number of factors. Sometimes, the child's clinical profile provides strong clues as to the method or methods that are likely to be most effective with his or her unique set of problems. For example, we might predict that a child with significantly high or low muscle tone will respond best to a neurodevelopmental approach, while a child who is extremely oversensitive to sensory input, and, as a result, avoids many play situations, might respond better to sensory integration therapy. Sometimes, the personal interests expressed by the child and his or her family may suggest the appropriateness of an alternative approach. The child who has balance and postural control difficulties and who is passionate about animals may respond more effectively to therapeutic horseback riding than a child who is more cautious and fearful around animals. The family who has a home swimming pool may be able to provide home carry-over of strategies learned through aquatic therapy more easily than the family who has to travel to the local public swimming pool.

The therapist must also consider his or her own training with different methodologies, and will probably show a bias towards those methods with which he or she has had the most training and clinical experience. In addition, therapists must unfortunately take into consideration any external limits to their ability to select the treatment approaches that they consider to be ideal. For example, some interventions require significant home carry-over by parents to be effective. This may be fine for some families, but if the family consists of a single working mother who has limited time and energy after work, and who is uncomfortable assuming the role of "therapist," it may be necessary" to reconsider the approach. Insurance companies may be unwilling to pay for the extended duration of therapy needed for some developmental approaches, requiring the therapist to focus more on helping the child and family to quickly develop compensatory approaches.

(Kurtz, 2008, p.63)

Table 11

Physiological Adaptations to Resistance Training	
Variable	**Resistance training adaptations**
Performance	
Muscular strength	Increases
Muscular endurance	Increases for high power output
Aerobic power	No change or increases slightly
Maximal rate of force production	Increases
Vertical jump	Ability increases
Anaerobic power	Increases
Sprint speed	Improves
Muscle fibers	
Fiber size	Increases
Capillary density	No change or decreases
Mitochondrial density	Decreases
Myofibrillar packing density	No change
Myofibrillar volume	Increases
Cytoplasmic density	Increases
Myosin heavy-chain protein	Increases in amount
Enzyme activity	
Creatine phosphokinase	Increases
Myokinase	Increases
Phosphofructokinase	Increases
Lactate dehydrogenase	No change or variable
Sodium-potassium ATPase	Increases
Metabolic energy stores	
Stored ATP	Increases
Stored creatine phosphate	Increases
Stored glycogen	Increases
Stored triglycerides	May increase
Connective tissue	
Ligament strength	May increase
Tendon strength	May increase
Collagen content	May increase
Bone density	No change or increases
Body composition	
% body fat	Decreases
Fat-free mass	Increases

(Baechle & Earle, 2008, p.96)

Table 12

Physiological Adaptations to Aerobic Endurance Training	
Variable	**Resistance training adaptations**
Performance	
Muscular strength	No change
Muscular endurance	Increases for low power output
Aerobic power	Increases
Maximal rate of force production	No change or decreases
Vertical jump	Ability unchanged
Anaerobic power	No change
Sprint speed	No change
Muscle fibers	
Fiber size	No change or increases slightly
Capillary density	Increases
Mitochondrial density	Increases
Myofibrillar packing density	No change
Myofibrillar volume	No change
Cytoplasmic density	No change
Myosin heavy-chain protein	No change or decreases in amount
Enzyme activity	
Creatine phosphokinase	Increases
Myokinase	Increases
Phosphofructokinase	Variable
Lactate dehydrogenase	Variable
Sodium-potassium ATPase	May slightly increase
Metabolic energy stores	
Stored ATP	Increases
Stored creatine phosphate	Increases
Stored glycogen	Increases
Stored triglycerides	Increase
Connective tissue	
Ligament strength	Increases
Tendon strength	Increases
Collagen content	Variable
Bone density	No change or increases
Body composition	
% body fat	Decreases
Fat-free mass	No change

(Baechle & Earle, 2008, p.128)

Table 13

What are the Improvements in Performance from Anaerobic Exercise?	
Muscular Strength A review of more than 100 studies showed that mean strength increased approximately 40% in "untrained," 20% in "moderately trained." 16% in "trained," 10% in "advanced," and 2% in "elite" participants over periods ranging from four weeks to two years (9). Heavier loads are most effective for fiber recruitment. The effects of training are related to the type of exercise used, its intensity, and its volume. With trained athletes, higher intensity and volume of exercise are needed in order for adaptations to continue (131). **Power** Heavy resistance training with slow velocities of movement leads primarily to improvements in maximal strength, whereas power training (i.e., lifting light-to-moderate loads at high velocities) increases force output at higher velocities and rate of force development. Peak power output is maximized during the jump squat with loads corresponding to 30% to 60% of squat 1 RM (13, 216). For the upper body, peak power output can be maximized during the ballistic bench press throw using loads corresponding to 46% to 62% of 1 RM bench press (12). **Local Muscular Endurance** Cross-sectional data in anaerobic athletes have shown enhanced muscular endurance and subsequent muscular adaptations consistent with improved oxidative and buffering capacity (110, 118). Skeletal muscle adaptations to anaerobic muscular endurance training include fiber type transitions and increases in mitochondrial and capillary numbers,.	buffering capacity, resistance to fatigue, and metabolic enzyme activity **Body Composition** Resistance training can increase fat-free mass and reduce body fat by 1 % to 9% (59). Increases in lean tissue mass, daily metabolic rate, and energy expenditure during exercise are outcomes of resistance training. **Flexibility** Anaerobic training potentially can have a positive impact on flexibility, primarily if the individual has poor flexibility to begin with. The combination of resistance training and stretching appears to be the most effective method to improve flexibility with increasing muscle mass. **Aerobic Capacity** Heavy resistance training does not significantly affect aerobic capacity unless the individual is initially deconditioned. The exception is in relatively untrained people, who can experience increases in V02max ranging from 5% to 8% as a result of resistance training. Circuit training and programs using high volume and short rest periods (i.e., 30 seconds or less) have been shown to improve V02max (71). **Motor Performance** Anaerobic training enhances motor performance; the magnitude of change is based on the specificity of the exercises or modalities performed. Resistance training has been shown to increase running economy, vertical jump, sprint speed, tennis serve velocity, swinging and throwing velocity, and kicking performance (130).

(Baechle & Earle, 2008, p.113)

Table 14

Youth Resistance Guidelines	
Each child should understand the benefits and risks associated with resistance training. Competent and caring fitness professionals should supervise training sessions. The exercise environment should be safe and free of hazards, and the equipment should be in good repair and properly sized to fit each child. Dynamic warm-up exercises should be performed before resistance training. Static stretching exercises should be performed after resistance training. Carefully monitor each child's tolerance to the exercise stress. Begin with light loads to allow appropriate adjustments to be made. Increase the resistance gradually (e.g., 5% to 10%) as strength improves.	Depending on individual needs and goals, one to three sets of 6 to 15 repetitions on a variety of single- and multijoint exercises can be performed. Advanced multijoint exercises, such as the snatch and clean and jerk, may be incorporated into the program provided that appropriate loads are used and the focus remains on proper form. Two to three nonconsecutive training sessions per week are recommended. When necessary, adult spotters should be nearby to actively assist the child in the event of a failed repetition. The resistance training program should be systematically varied throughout the year. Children should be encouraged to drink plenty of water before, during, and after exercise.

(Baechle & Earle, 2008, p.150)

Table 15

Individual Difference Factors that can Contribute to Differences in People's Movement	
Abilities	Finger dexterity, stamina, trunk strength
Attitudes	Open closed, or neutral to new experiences
Body type	Stocky, tall, short, lean muscular, round
Cultural background	Ethnicity, race, religion socio-economic status
Emotional makeup	Boredom, excitement, fear; joy
Fitness level	Low, moderate, high
Learning style	Visual, verbal, kinesthetic
Maturational level	Immature, intermediate, mature
Motivational level	Low, moderate, high
Previous social experiences	One-on-one, small group, large group
Prior movement experiences	Recreational, instructional, competitive

(Schmidt & Wrisberg, 2000, p.27)